VOLUME VI. NUMBER 6

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR

C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

W. F. KING
Chief Astronomer
Ottawa

R. F. STUPART
Director of the Meteorological Service of Canada, Toronto

J. S. PLASKETT
Dominion Observatory
Ottawa

PUBLISHED BI-MONTHLY

NOVEMBER-DECEMBER, 1912

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON,
28 ESSEX ST., STRAND, LONDON.

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. VI. NOVEMBER DECEMBER, 1912. No. 6

Jules Henri Poincaré	*Alfred T. DeLury*	309
Photographing Lightning	*A. Steadworthy*	322
The Geodetic Survey of Canada	*Charles A. Bigger*	324
The Orbit of β Coronæ Borealis	*J. B. Cannon*	343
Meetings of the Society		
At Toronto	*L. G.*	350
At Ottawa	*R. E. DeL.*	353
At Hamilton	*T. H. W.*	356
At Peterborough	*D. B. M.*	358
Notes from the Meteorological Service		
Report of the Weather in Canada, October-November	*R. F. S.*	360
Magnetic Observations	*R. F. S.*	363
Earthquake Records at Toronto and at Victoria, B. C.	*J. Y.*	364
Astronomical Notes		
Is the Earth Shrinking		366
The Distribution of Galactic Objects		366
The Origin of the Himalaya Mountains		367
The Southern Milky Way		367
Rotation of the Earth		368
The Systematic Motions of Sun-Spots		368
An Instance of Scientific Accuracy		369
A Comet that Discovered a Man	*J. R. C.*	370
Notes and Queries	*C. A. C.*	371
Index to Vol. VI.		

Editorial communications should be addressed to C. A. Chant, University of Toronto, Toronto, Ont.

Business correspondence, remittances, etc., should be addressed to Chas. P. Sparling, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 35 cents.

Subscription to the *Journal* is included in membership fee.

Anyone wishing to purchase a telescope may correspond with the Secretary, Toronto.

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

OFFICERS FOR 1912

Honorary President—W. F. KING, C.M.G., LL.D., Chief Astronomer, Ottawa.
President—Professor LOUIS B. STEWART.
First Vice-President—J. S. PLASKETT, B.A.
Second Vice-President—A. D. Watson, M.D.
Secretary—J. R. COLLINS. *Treasurer*—CHAS. P. SPARLING.
Recorder—LACHLAN GILCHRIST, M.A. *Librarian*—DR. W. M. WUNDER.
Curator—ROBERT S. DUNCAN.

Council—The above Officers, and the following members: G. PARRY JENKINS, F.R.A.S., Toronto; Rev. I. J. KAVANAGH, S.J., D.Sc., Montreal; Rev. Dr. MARSH, F.R.A.S., Peterboro; A. F. MILLER, Toronto; Sir JOSEPH POPE, K.C.M.G., Ottawa; R. M. STEWART, M.A., Ottawa; and Past Presidents ANDREW ELVINS, JOHN A. PATERSON, K.C., M.A.; R. F. STUPART, F.R.S.C.; Professor C. A. CHANT, W. BALFOUR MUSSON, Professor A. T. DELURY; and the presiding officer of each Centre as follows: J. S. PLASKETT, B.A.; H. O. FISKE, C.E.; WM. BRUCE, J.P.; N. MACMURCHY, B.A.; Professor N. B. MCLEAN and HENRY WESTOBY, Esq.

OTTAWA CENTRE

Local President—J. S. PLASKETT, B.A.
Vice-President—R. M. STEWART, M.A.
Secretary—CARL ENGLER, B.A. *Treasurer*—C. C. SMITH, B.A.
Council—W. E. HARPER, B.A.; F. A. MCDIARMID, B.A.; R. E. DELURY.

PETERBOROUGH CENTRE

Local President—H. O. FISKE, C.E. *Vice-President*—T. A. S. HAY, C.E.
Secretary-Treasurer—REV. D. B. MARSH, D.Sc., F.R.A.S.
Curator—H. O. FISKE, C.E. *Librarian*—T. A. S. HAY, C.E.
Auditor—FRANK ADAMS
Council—A. J. SEGER, D. WALKER, B.A.; T. ELLIOTT, H. CARVETH, S. J. KEYES, A. J. JOHNSTON, PHM.B.; D. E. EASON, B.A.Sc.

HAMILTON CENTRE

Local President—WM. BRUCE, J.P.
First Vice-President—E. H. DARLING, A.M.C.S., C.E.
Second Vice-President—W. A. ROBINSON.
Secretary—T. H. WINGHAM, B.A. Sc. *Treasurer*—SENECA JONES.
Council—REV. R. E. M. BRADY, D.Sc.; REV. I. J. MORTON, G. PARRY JENKINS, F.R.A.S.

REGINA CENTRE

Hon. President—WM. TRANT. *Hon. Vice-President*—P. MCARA, Jr.
President—N. MACMURCHY, B.A.
First Vice-President—H. LANG. *Second Vice-President*—MRS. J. F. BRYANT.
Secretary—H. S. MCCLUNG. *Treasurer*—J. F. BRYANT
Council—C. B. KEENLEYSIDE, J. E. DOERR, Miss E. D. CATHRO.

WINNIPEG CENTRE

President—PROFESSOR NEIL B. MACLEAN.
Vice-President—
Secretary-Treasurer—C. E. BASTIN.
Council—MRS. L. B. IRELAND, H. C. HOWARD, R. E. COLLINS, REV. FATHER J. BLAIN, S.J.; MRS. KEMP.

GUELPH CENTRE

Honorary President—COLONEL A. H. MACDONALD, K.C.
Honorary Vice-President—DR. W. F. SAVAGE.
President—HENRY WESTOBY, Esq.
First Vice-President—PROFESSOR W. H. DAY, B.A.
Second Vice-President—DR. J. LINDSAY. *Secretary*—H. E. S. ASBURY.
Recorder—J. T. LUTON. *Treasurer*—H. J. B. LEADLAY.
Council—DR. A. H. HOBBS, REV. W. J. WILSON, W. C. MCLAREN, W. TYTLER, MRS. H. J. B. LEADLAY AND MRS. W. O. STEWART.

PLATE XXX.

JULES HENRI POINCARÉ

Born April 29, 1854. Died July 17, 1912.

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR

C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

W. F. KING
Chief Astronomer
Ottawa

R. F. STUPART
Director of the Meteorological
Service of Canada, Toronto

J. S. PLASKETT
Dominion Observatory
Ottawa

VOLUME VI. 1912

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON,
28 ESSEX ST., STRAND, LONDON.

CONTENTS OF VOLUME VI.

I. JANUARY-FEBRUARY

Theories of World Making - - - - *A. T. DeLury* 1
Location of Epicentres for 1911 - - - *Otto Klotz* 15
The Astronomical and Astrophysical Society of America—Washington Meeting - - *C. A. Chant* 24
The Spectrum of Nova Geminorum - - - *J. S. Plaskett* 27
Meetings of the Society at Toronto, 37; at Ottawa, 40; at Hamilton, 47; at Peterborough, 49; at Regina, 51. Notes from the Dominion Observatory, 53. Notes from the Meteorological Service, 56; Astronomical Notes, 63. Notes and Queries, 68.

II. MARCH APRIL

Meteorology in Canada - - - - *R. F. Stupart* 75
Strange Celestial Visitors—Comets and Meteors - *C. A. Chant* 88
Astronomy as a Recreation - - - - *Joseph Pope* 99
The Moon's Orbit Around the Sun - - - *A. B. Turner* 117
Meetings of the Society at Toronto, 120; at Ottawa, 124; at Hamilton, 129; at Peterborough, 131. Notes from the Meteorological Service, 133. Astronomical Notes, 139. Notes and Queries, 144.

III. MAY-JUNE

Precise Levelling in Canada - - - - *F. B. Reid* 151
A Long-Period Spectroscopic Binary - - - *W. E. Harper* 179
Orbit of ξ Persei from the H and K Lines - - *J. B. Cannon* 188
Meetings of the Society at Toronto, 197; at Ottawa, 198; at Hamilton, 200; at Peterborough, 200; at Guelph, 202. Notes from the Meteorological Service, 203. Astronomical Notes, 211. Notes and Queries, 216.

IV. JULY AUGUST

The Dark Structures in the Milky Way - - *T. E. Espin* 225
The Spectroscopic Binary θ^2 Tauri - - - *J. S. Plaskett* 231
In the Background of the Stars - - - *C. A. Chant* 240
Meetings of the Society at Toronto, 246; at Peterborough, 246; at Regina, 247. Notes from the Meteorological Service, 251. Astronomical Notes, 258. Notes and Queries, 262.

V. SEPTEMBER-OCTOBER

Further Observations of θ Aquilæ - - - *W. E. Harper* 265
Astronomical and Astrophysical Society of America—
Pittsburgh Meeting - - - - *J. S. Plaskett* 272
Photographing Halley's Comet with Home-Made Apparatus *A. Young* 281
The Responsibilities of an Observatory Staff - *Frank Schlesinger* 283
Notes from the Dominion Observatory, 290. Notes from the Meteorological Service, 293. Astronomical Notes, 299. Notes and Queries, 304.

VI. NOVEMBER DECEMBER

Jules Henri Poincaré - - - - - *Alfred T. DeLury* 309
Photographing Lightning - - - - *A. Steadworthy* 322
The Geodetic Survey of Canada - - - *Charles A. Bigger* 324
The Orbit of ζ Coronæ Borealis - - - *J. B. Cannon* 343
Meetings of the Society at Toronto, 350; at Ottawa, 353; at Hamilton, 356; at Peterborough, 358. Notes from the Meteorological Service, 360. Astronomical Notes, 366. Notes and Queries, 371.

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. VI. NOVEMBER DECEMBER, 1912. No. 6

JULES HENRI POINCARÉ*

BY ALFRED T. DELURY

WHEN in July last it was announced that Poincaré was no more, workers in many fields of enquiry were, through the tragic circumstance of death, startled into a realization of the debt their science owed to him and of the loss suffered in the passing of so vast a soul. For many years the science in which our Society is chiefly interested had claimed no small part of his attention, and his contributions to it, while for the most part outside the range of the general student, are numerous and profound. Fitting is it, then, on resuming our meetings for the year, that we devote an evening to a review, necessarily inadequate, of his work, and to the contemplation of a rich, full and stimulating, if all too short, life.

Henri Poincaré was born April 29, 1854, at Nancy, of Lorraine, a part of France notably fecund of genius. His family were, on the one side, small land-holders warmly attached to

* Report of an address delivered before the Royal Astronomical Society of Canada, November 5, 1912.

country interests, on the other side, of the professional class, lawyers, physicians, pharmacists and soldiers. His father was a practising physician and a member of the Faculty at Nancy. With the family lived an uncle, a graduate of the École Polytechnique, an officer of the state in the department of *Ponts et Chausées*. The youthful Poincaré was heir then to the double tradition of learning and provincial simplicity of life.

As a child he was alert, even precocious, and stories illustrative of his early awakened interest in science survive. One only will be told, and this finds him at an early age. The story runs that when only nine months old, one evening, as darkness fell, his eye caught a star and he called his mother's attention to it; as others shone out he espied them and became excitedly intent in his search for others, so much so that he was with difficulty quieted, and brought into a mood for sleep. In this, one may choose to see a presage. At the age of five a serious illness threatened for a time to deprive him of the power of speech; it left him weak, and intensified in him a certain native shyness. Illness often has a maturing influence, and it seems to have affected the child Poincaré in this way. He was less drawn to childish sports and more to reading, and the reading of books dealing with simple science rather than fairy tales and romances. His first formal instruction was given at his home in a charmingly informal manner by an old retired and scholarly schoolmaster. Everything was treated as a matter to be talked about, and the talk was of everything. The result was that when he had to take his place in school, and feel the yoke of method, he brought to his studies a certain general knowledge and a free and quickened curiosity.

He entered the lycée of his native city at the age of nine and followed his studies there for eleven years. He showed an aptness in all his courses, with a marked leaning to letters. When, however, he reached the class in which the pupils became acquainted with geometry, there was no longer any doubt as to what studies were to claim him. His teacher hastened to tell his mother that her son was destined to be a great mathematician,

and each year of work at the lycée strengthened the faith in the prediction. It was while he was still a lycéean that he was a witness of the humiliation of his native land, Nancy itself being occupied by the victorious Germans. With some of the hideous realities of war he came into close contact while assisting his father who, as physician, was caring for the sick and wounded. Scanning the war bulletins and interpreting to himself the reports of operations in the only papers that were within his reach, he came to understand the German language. Nancy was in the territory occupied by the Germans after the war, and the last of his many collegiate honors were conferred as, in the same hall, was announced the withdrawal of the foreign troops. He had taken, in 1871, the degrees of Bachelor of Letters and Bachelor of Sciences, and in 1873 in the competitive examinations for entrance into the École Polytechnique and the École Normale he had been ranked first and fifth respectively. His college days at Nancy were at a close; the time for the decision as to his life's work had come.

He chose to enter the École Polytechnique, the great school leading to careers in the army and in such services as are administered by the department of *Travaux Publiques*, the École Normale opening up immediately careers in the higher teaching and favoring, perhaps, studies pursued for scientific rather than practical ends. What decided Poincaré, without marked aptitude for the practical, in electing as he did, it is difficult to say. His course for the two years in the École Polytechnique was a brilliant one, in all that related to purely scientific studies, and of these mathematical studies made up the greater part. Originality and resource characterized his work, and his very eccentricity of manner, and method of study seemed to mark him as one destined to enlarge the boundaries of science.

When in 1875 he had completed the course, he decided to enter the *Service des Mines*, and became enrolled as Élève Ingénieur at the École des Mines. This meant a great change in studies and in mode of life. His course allowed or required him to make visits, for observation and study, to other countries.

In the freer life which he now enjoyed he became responsive to new and varied influences and the stimulus that they bring. His interest in pure science did not abate, and the year 1876 saw him *Licencie ès Sciences*; in 1879 he was awarded the degree of *Docteur ès Sciences*, his thesis being *Sur les proprietes des fonctions definies par les equations aux differentielles partielles*. In 1879 he was named *Ingenieur Ordinaire des Mines*, and was for some time in charge of the mines at Vassoul. In the fall of 1879 he was, by request, transferred to the state service in the higher teaching and placed in charge of the Course in Analysis at the Faculty of Sciences at Caen.

These were important years for Poincaré, the years in which the peculiar character of his genius was to reveal itself. In France the activity in mathematical work was very striking. Time was still adding to the suggestive power of Hermite, and near to him were many auxiliary sources, stars shining amid the effulgence,— and a star of the first order was rising. In Germany, the inspiration of the discoveries and teaching of Weierstrass was expressing itself in results that were quickening mathematical interest in every land. These were the favoring conditions,— favoring in that they served to accentuate his individuality and choice, and not to assimilate his ideas and make them tributary to a school of thought.

His early papers — his thesis and a memoir offered in competition for the *Grand Prix des Sciences Mathématiques* — were on differential equations, that meeting ground for so many mathematical theories. This memoir, though it did not call for the award, elicited from Hermite, who reported on the papers submitted, the warmest commendation, with the counsel that the writer follow up certain lines of enquiry then traced. The two papers in question show that Poincaré had come to realize that advances in the treatment of differential equations were dependent upon advances in the general theory of functions. A reference to his work, by Hermite, in a paper contributed to *Crelle's Journal*, in December, 1880, would indicate further that he was giving thought to this theory.

In February, 1881, appeared the first of a long line of notes and papers on the theory of functions,— papers enlarging the prospect in analysis and revealing discoveries generally regarded as the richest offerings of his genius. The earliest of these notes appeared in the *Comptes Rendus*, announcing, under such titles as *Sur les fonctions fuchsiennes*, *Sur les groupes Kleinéens*, *Sur les fonctions à espaces lacunaires*, the results of his investigations. The new theories were elaborated in a brilliant series of memoirs published in the earlier volumes of *Acta Mathematica*. It would be difficult here to explain, in any detail, the significance and importance of these discoveries, and I shall limit myself to the citing of only one of the most striking consequences, the fact that through the newly introduced functions the study of the most general non-uniform analytic functions of one variable is reduced to the study of uniform functions.

While these theories were being developed, Poincaré's interest in the subject that first claimed, or claimed a first place in, his attention, namely, differential equations, only increased. To these years we owe the remarkable series of papers, *Sur les courbes définies par les équations différentielles*.— (Four parts, *Liouville's Journal*, 1881-1886).

In the fall of 1881, Poincaré was named to the Faculty of Sciences at Paris as *Maître de Conférences d'Analyse* and in 1883 the duties of *Répétiteur d'Analyse à l'Ecole Polytechnique* were added. He became *Chargé du Cours de Mécanique Physique et Expérimentale* in the Faculty of Sciences, and the next year was appointed to the Professorship of Mathematical Physics. These later appointments reflected rather than determined the line of progress, or direction of interest, in Poincaré's mind, and, in the choice, he was faithful to the traditions of French Science, for, though striking instances to the contrary will occur to every one, we may say that in the main the French mathematicians have been able physicists, and French physicists able mathematicians.

As professor of Mathematical Physics, Poincaré, year after year, chose a new subject for his course, and brought his

strength to bear on the outstanding questions in the different branches of physical science. His lectures were published, and the charm and skill of his manner of exposition allowed to impress those who could not hear him. The favorable reviews of these volumes as they appeared show the esteem in which they were held by those competent to judge. Two of them I have at least to name, for they appear to me ideal treatments of their subjects. I refer to the *Théorie Analytique de la Propagation de la Chaleur*, and the *Théorie du Potentiel Newtonien*.

We may now turn to another field of application of analysis and in particular of differential equations, a field which might be included in mathematical physics, but which is well designated by a special title,— the field of mathematical astronomy or we may say *mécanique céleste*, including *mécanique analytique* as applied to astronomical problems. Early in 1885, appeared certain important notes in the *Comptes Rendus* indicating valuable results, obtained by Poincaré, in relation to the behavior of a fluid mass under rotation, and later in the year there was published in *Acta Mathematica* his great memoir *Sur l'équilibre d'une masse fluide en rotation*. Jacobi had shown that the ellipsoid of revolution, the received stable form of a fluid mass rotating under the action of gravity, would, under contraction and increase of angular velocity, reach a stage that marked a limit to stability when the ellipsoidal body would pass into a new series of forms, ellipsoidal but with three unequal axes, into what, in picturesque language, is called a series of cigar-shaped forms. Poincaré shows that a limit to stability is again reached when a series of pear-shaped forms would follow. To convey an idea of the significance of this memoir in an important side of astronomy let me quote from the address of Professor Darwin, when presenting to Poincaré, in 1900, the medal of the Royal Astronomical Society of London.

"This apparently abstract result elucidates the evolution of planetary systems in a very interesting way. Let us consider a rotating liquid mass slowly cooling. If the cooling is slow enough internal friction will cause the whole to revolve through

out with the same angular velocity. At first, when the density is small, the figure will be an ellipsoid of revolution but slightly flattened; and as it cools the flattening will increase until at a certain stage the figure of revolution ceases to be a figure of equilibrium, and the ellipsoid commences to have an equatorial protuberance; it passes, in fact, into one of Jacobi's ellipsoids. The ellipsoid then lengthens until at a certain stage it begins to acquire an unsymmetrical furrow in a plane parallel to the axis of revolution, and it becomes pear-shaped, with the axis of revolution at right angles to the core of the pear. 'The larger part of the matter tends to approach the spherical form, whilst the smaller part projects from the ellipsoid at one of the extremities of the longer axis, as though it were trying to detach itself from the larger part of the mass. It is difficult to state with certainty what will happen then if the cooling continues, but one may suppose that the mass will go on deepening its furrow more and more, and then it will at last divide itself into two separate bodies by the throttling of the middle part.' It is clear that a process of this kind may have played its part in the evolution of celestial systems, and the speculation seems to meet with confirmation from the forms observed in many nebulæ."

". . . . Poincaré's paper is one that will always mark an important epoch in the history not only of evolutionary astronomy, but of the wider fields of general mechanics."

Professor Darwin has made signal use of this theory, for based on it is his brilliant theory of the evolution of the earth-moon system.

On the problem of the three bodies, Poincaré published many important papers. His great memoir, *Sur le Problème des trois Corps, et les équations de la Dynamique*, won for him the prize founded by the King of Sweden and Norway. It was published in *Acta Mathemtica* in 1890. Soon afterwards, in 1892, appeared the first volume of his important work *Les Méthodes Nouvelles de la Mécanique Céleste*. The two later volumes appeared in 1894 and 1899. As the name suggests, their subject matter is not the classical theory, but a presentation of the newer methods of

treatment of the more important problems. The theories and treatments associated with the names of Hill, Gyldén, Linstedt, are discussed and examined. Where an investigator has had the *hardiesse* to make use of a process without as yet having complete logical warrant, as in the case of Hill's employing the infinite determinant, Poincaré sets himself the problem of making the foundations sure. His own contributions are developed incidentally to these critical examinations of theories.

It will serve to bring us nearer to what Poincaré had in mind in writing the *Nouvelles Méthodes*, of which Darwin has said that "it is probable that for half a century to come it will be the mine from which humbler investigators will excavate their materials." To quote from his Introduction:

"The final object of Celestial Mechanics is to determine whether the law of Newton, of itself alone, explains all astronomical phenomena. The one way to accomplish this is to make observations as precise as possible and then to compare them with the results of computation. These results are only approximate, and it would serve no purpose to compute to a higher place of decimals than the observations can reveal. It is useless then to demand of the computation a higher degree of precision than of the observations; but one ought not to be satisfied with a lower degree. Further the approximations with which to-day we are content, will be in time insufficient. . . . . .

"The time when we shall be obliged to give up the older methods is, beyond doubt, still far away; but the theoretical worker is obliged to anticipate it, since his work must precede, and often by many years, that of the computer. . . . . .

"The discussion of the convergence of these developments must claim the attention of mathematicians, first for the reasons explained, and further because the object of Celestial Mechanics is not attained when we have calculated ephemerides, more or less approximate, without being able to estimate the degree of approximation. If we arrive at a divergence between these ephemerides and the observations, it is necessary that we be able to discover whether Newton's law is in defect, or that the explan-

ation lies in an imperfect theory. It is important then to determine a superior limit to the error, and this problem has not hitherto sufficiently engaged attention. Now the methods which allow us to discuss the convergence give us at the same time this upper limit, and their importance and utility is enhanced. The reader will not then be astonished at the place which I have given them, in this work, although probably I have not derived from them all the results that might have been of service.

"I have occupied myself with these questions, and to them I have devoted a memoir published in Volume XIII. of *Acta Mathematica*. There above all I set myself the problem of presenting the few results relative to the Problem of Three Bodies which can be established in the complete rigour demanded by mathematics. This rigour it is that constitutes the value in my theorems on periodic, asymptotic, and doubly asymptotic solutions. In them may be found a firm foundation on which one may build with confidence. . . . . .

"It seemed to me on the other hand, that my results would allow me to unite in a sort of synthesis the greater part of the new methods recently proposed, and this it was that decided me to undertake the present work."

In 1896, on the death of Tisserand, Poincaré chose to be appointed to the Professorship in Mathematical Astronomy and Celestial Mechanics. His lectures in the earlier years of this chair were published under the title *Leçons de Mécanique Céleste*.

One of his latest publications was his lectures on theories of cosmogony. In this we have a singularly attractive discussion of the different hypotheses that have been made to afford a foundation for an admitted evolution.

Reference should be made also to certain important papers on tides, but enough has been said to indicate that in astronomy, the aristocrat of the sciences, he has made advances that alone would render his name illustrious for all time.

On his mathematical work much more might be said, but further comments must be brief. He could not have been associated with Hermite without recognizing the contact of his investiga-

tions with the theory of forms and the higher arithmetic and algebra. His attention too was early drawn to the non-euclidian geometry. The postulate of Euclid on parallel lines had, for reasons now familiar to all, seemed to challenge proof. Implied in it is the unboundedness, and the infinitude of space, and for a long time it was not seen that this involved in it the impossibility of proof and marked it as a veritable postulate. Early in the century which saw the greater part of Poincaré's activity, the epoch-making discoveries of Lobatchevsky and Bolyai had settled the question. Poincaré realized to the full the philosophical significance of the new geometries, and, in a note recording the process of his mind in reaching certain results, bears testimony to its suggestiveness in the domain of pure analysis. He wrote a number of brilliant papers on this subject, and supplemented Hilbert's work on the foundations of geometry. For his studies in this domain he was in 1904 awarded the Lobatchevsky gold medal of the Mathematical Society of Kasan, and in 1905 the Bolyai prize by the Hungarian Academy of Sciences. To the *Analysis Situs* also he made valuable contributions.

It is now in place to say that the philosophical side of the subjects of his thought, the question of foundations, the rôle of logic, and of experience, strongly attracted him. Papers dealing with this side of the sciences were contributed to several reviews and periodicals. Certain of these were collected and published in three volumes *La Science et l'Hypothèse*, *La Valeur de la Science*, *Science et Méthode*. The literary excellence of these essays, and the boldness and directness of the speculation, won for them at once an astonishing popularity. They were translated into many languages and through them many who would otherwise have been untouched directly by Poincaré's thought, came to know something of the workings of his mind.

Of the subjects treated only one will be selected for comment, that on the nature of mathematical reasoning. The author considers the fact that the striking quality of mathematical reasoning is its logical character and asks wherein resides the fruitful principle certainly present in mathematics, while in logic

we have, to be sure, a criterion, a touchstone for argument, but no source of new life. He finds this in the method of complete or mathematical induction. This may be illustrated very simply. For example, we notice that if we have the succession of terms $1 + 3 + 5 + 7 + \ldots\ldots$, the sums of 1, 2, 3, 4, ... terms are 1^2, 2^2, 3^2, 4^2, ... , this as far as we choose to add. We may feel that we have a warrant for assuming that the correspondence will continue but it does not follow that it *must* continue. Let us assume that the sum of n terms is n^2, *i. e.*, that

$$1 + 3 + 5 + \ldots + (2n - 1) = n^2$$

Then the sum of $n + 1$ terms is this sum increased by the next term, or $2n + 1$. This yields $n^2 + 2n + 1$, which is $(n + 1)^2$. Thus if the correspondence holds out to the *nth* term it must hold for $n+1$ terms. But it is valid for 1, 2, 3, 4 . . . terms: hence it must hold for 5, 6, 7, 8. . . . . or any number of terms. This induction is accordingly perfect. It comprehends an infinity of syllogisms and in it lies the element necessary to creation in the domain of mathematics. Poincaré gives a very illuminating treatment of the elementary laws of arithmetic, and his whole argument is very stimulating.

It would go without saying that the work of this keen investigator would bring him many honours, many acknowledgments of distinction. In 1887 he became a member of the Academy of Sciences and in 1908 the *Académie Francaise* opened its doors to him. He was a member of all the principal scientific societies and academies of the two continents, and was awarded many prizes and medals by scientific bodies. He presided over the meetings of the Third International Congress of Mathematicians in Paris, 1900.

While at Rome, at the Mathematical Congress of 1908, he was taken seriously ill, and was unable to be present at the later sessions of the meeting. He was, in time, able to resume his work, and his many friends came to feel that, comparatively young, he had many years before him. This, however, was not to be. The ailment returning or persisting, a surgical operation

was counselled. For a short time after the operation, all seemed well, but unexpectedly and suddenly the end came.

Mathematicians, in respect to the outstanding character of their genius have been, so far as they have been creative, assigned to two classes, the intuitionists and analysts. One of the most interesting of Poincaré's philosophical papers deals with this very matter, and in considering the veritable nature of intuition, he would claim that intuition is essential to invention. He distinguishes the intuition of pure number, necessary to the creative analyst, from sensible intuition, or we may say imagination. The distinction exists but is not easily marked; one may name striking cases illustrative of each class, and cases in which each class might be illustrated. The variety presented by Poincaré's own achievements adds to the difficulty of realizing that the two kinds of intuition are sharply separated. We may then not err if we regard his intellectual strength and activity as having been sustained and stimulated by both sources.

The loss to the scientific world, in the death of Poincaré, is keenly felt though it cannot be estimated. The touching and eloquent tributes paid his memory, at his grave, testify to the great variety of his intellectual interest, and to the outstanding quality of his work in different domains, as well as to the charm and beauty of his character. From a later and incidental appreciation you must allow me to quote. At the opening meeting of the International Congress of Mathematicians, in August last, Sir George Howard Darwin extended on behalf of the Cambridge Philosophical Society a welcome to the ancient city of colleges. In the course of his address he said: —

"The Science of mathematics is now so wide and is already so much specialized that it may be doubted whether there exists to-day any man fully competent to understand mathematical research in all its diverse branches. I, at least, feel how profoundedly ill-equipped I am to represent our Society as regards all that vast field of knowledge which we classify as pure mathematics. I must tell you frankly that when I gaze on some of

the papers written by men in this room I feel myself in the same position as if they were written in Sanskrit. . . . . .

"Up to a few weeks ago, there was one man who alone of all mathematicians might have occupied the place which I hold without misgivings as to his fitness: I mean Henri Poincaré. It was at Rome just four years ago that the first dark shadow fell on us of that illness which has now terminated so fatally. You all remember the dismay which fell on us when the word passed from man to man, 'Poincaré is ill'. We had hoped that we might again have heard from his mouth some such luminous address as that which he gave at Rome; but it was not to be, and the loss of France in his death affects the whole world."*

In one of his essays Poincaré comes to the question of the object of science. He dignifies the old assertion, that the motive of our strivings is the desire for truth, by a few noble sentences: "When I speak here of truth, doubtless I have at first in mind scientific truth, but I would speak also of *la verite morale*, of which what we call justice is only one aspect. It would seem that I err in the use of words, that under one name I embrace two things with nothing in common, that *la verite scientifique* which is demonstrated cannot be linked with *la verite morale* which is felt. And yet I cannot separate them, and those who love the one love the other. To find the one, as to find the other, we must require ourselves to free our spirit of prejudice and passion, we must attain to absolute sincerity. These two kinds of truth, once discovered, bring us the same joy; each as soon as perceived glows with the same brilliancy and we must see it or close our eyes. Last of all, they both attract us and both flee from us; they are never fixed; when we think we have reached them, we see that we have further to go, and he who follows them is condemned never to know repose." The search for truth thus largely conceived, he insisted on as the goal of human activity, and the one end worthy of it. What he thus on one occasion so finely expressed in words, his whole life affirmed.

* As this paper is passing through the press, the word comes that death has claimed the distinguished scholar whose generous estimate of a fellow-worker is here quoted.

PHOTOGRAPHING LIGHTNING

By A. Steadworthy

FOR the past fifteen years I have, during favorable thunder-storms at night, attempted photographing the lightning, and with a fair degree of success, as seen by the enlarged prints hanging in the halls of the Observatory. Obtaining such photographs at night is comparatively simple, but still requiring some discretion, judgment and patience.

To secure photographs of lightning in broad daytime is not quite so simple, in fact we read in *Cassell's Cyclopædia of Photography*, 1911, p. 337, "Lightning cannot be photographed during the daytime, as however dark the sky is, the sun is behind it and actinic enough to have an action upon the dry plate and make the flash invisible." In the following it will be found that the author of this statement is mistaken.

On the afternoon of the 10th July last, a thunder-storm travelling from the westward to the eastward, passed to the south of the Observatory at Ottawa. As there was a vivid display of lightning I determined to attempt photographing some of the bolts. I went to work methodically. I knew very well that the exposure could not be made as it is done at night. I first counted the rapidity with which the flashes followed each other, and found this to be approximately six per minute, *i. e.*, a flash every ten seconds. My camera was a Ruby, with a Cooke lens of 8·6 inches focus, using 32 diaphragm, and ¼-inch opening. The plates were 4¾ in. × 6½ in. Wellington Iso-Speedy. With this aperture, plate and light, to photograph the landscape would have required six seconds exposure. Evidently the exposure had to be considerably less, if the flash was to be visible on the plate. I decided on two seconds, (of course the photographing of the lightning is instantaneous) bearing in mind that I expected a flash about every

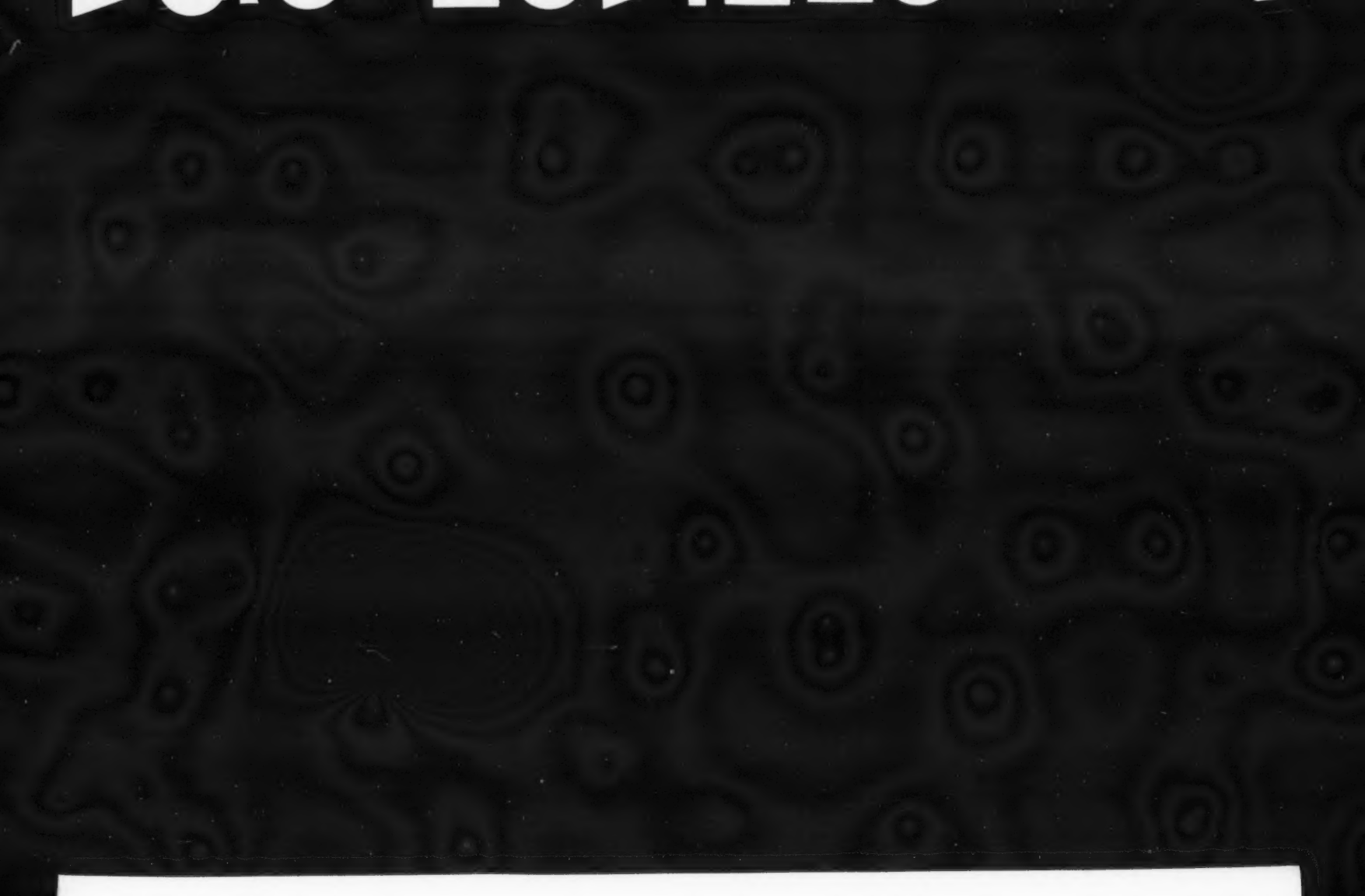


PLATE XXXI.

PHOTOGRAPH OF LIGHTNING.

Taken in daylight, July 10, 1912.

By A. Steadworthy, Dominion Astronomical Observatory, Ottawa.

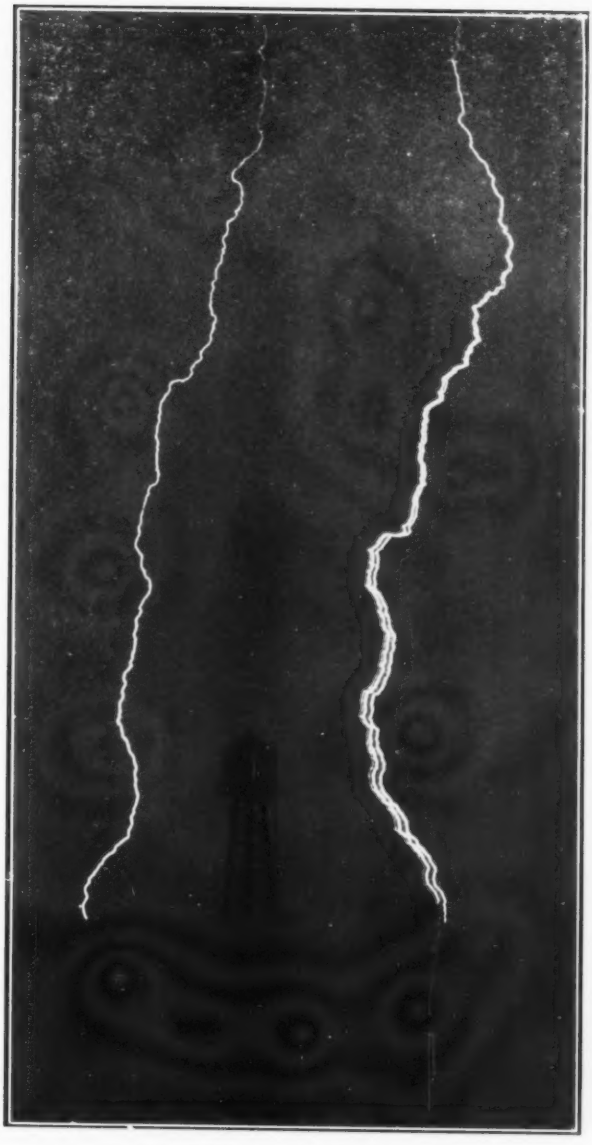
PLATE XXXII.

PHOTOGRAPH OF LIGHTNING.

Taken in daylight, July 10, 1912.

By A. Steadworthy, Dominion Astronomical Observatory, Ottawa.

PLATE XXXIII.



PHOTOGRAPH OF LIGHTNING.
Taken in daylight, July 10, 1912.
By A. Steadworthy, Dominion Astronomical Observatory, Ottawa.

ten seconds, and estimated the direction where it would take place as the storm was moving with considerable rapidity across my line of vision. I exposed in all, between 3.20 and 3.45 p. m. on the above day, twenty-one plates. For experimental purposes I exposed the first four plates the full six seconds, and as expected found no record thereon, although flashes took place. However, of the remaining seventeen plates I found three fine records, as reproduced herewith. I am absolutely sure that lightning occurred on some of the other fourteen plates, and that they were not recorded would point to the belief that lightning flashes vary very much more in actinic quality than one would infer from their visual quality. It is intended to investigate this spectroscopically.

In closing this brief note, it may be stated that six flashes were seen to follow the same path, rapidly succeeding each other.

After the last flash a luminous streak persisted in the sky for eight seconds, and faded away from the ends towards the middle.

DOMINION OBSERVATORY,
OTTAWA, CANADA
October 15, 1912.

THE GEODETIC SURVEY OF CANADA*

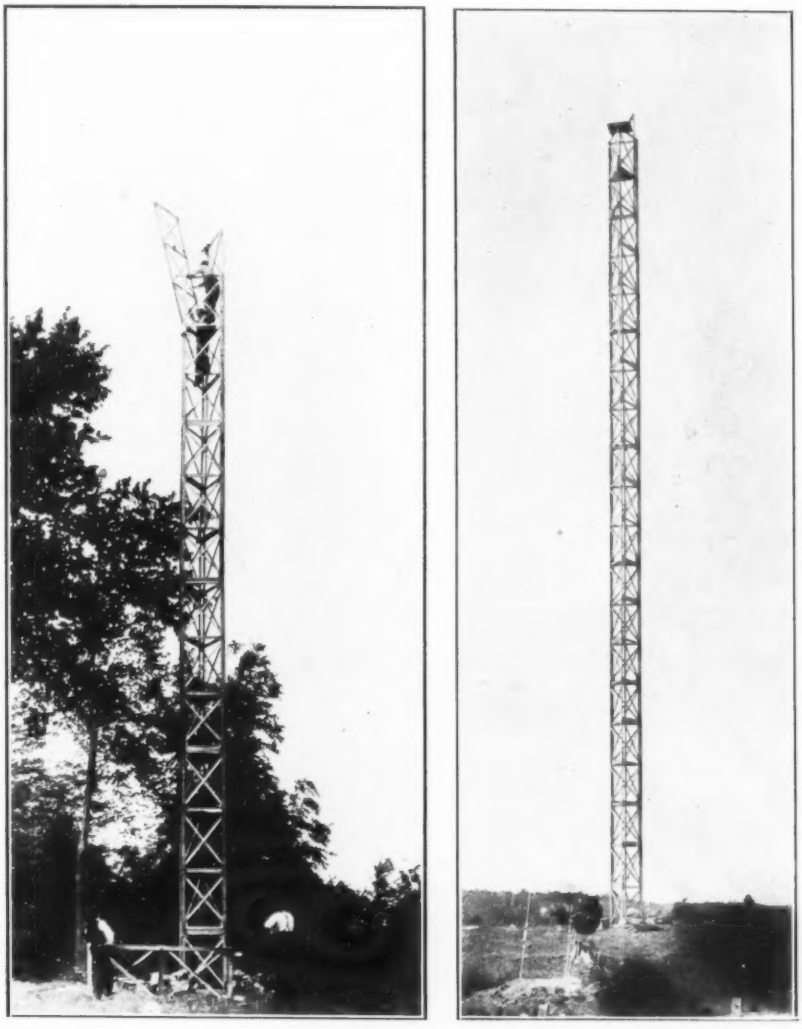
By Charles A. Bigger

GEODETIC SURVEYS have been in progress in other countries for more than a century ; an historical sketch of them is not within the scope of this paper, which is intended to describe the Canadian Survey, which has been spread over Canada in isolated sections from the Atlantic to the Pacific Ocean.

The visible signs of the existence and extension of the work consist in what may be termed skeleton towers, which in a general way are similar to other structures of well known utility, such as wind-pumps or deep-well boring apparatus. The material used in their construction is wood varying in size from two by four to eight by eight inches. These skeleton towers are observing stations ; on account of the necessity for intervisibility, they are erected on the highest ground within a radius of many miles. Thus they are seen from the public highways projected against the sky, and as they are scattered over the most thickly populated portions of Canada, the interest they have aroused is wide-spread and insistent, indicating a universal desire to know the story of the Survey.

As viewed against this most effective of all back-grounds, the sky, the observing towers present outlines which are essentially different from any of the structures heretofore familiar to the public. There is no central shaft and there are two structures — one within the other — and the outlines of these structures are curved instead of straight. The number and variety of questions that have been asked with reference to the reason for their sudden and unaccountable appearance in the midst of hitherto peaceful and law-abiding communities are more easily

* Read before the R.A.S.C. at Ottawa, October 10, 1912.



In course of erection Complete

PORTABLE RECONNAISANCE TOWER, CANADIAN GEODETIC SURVEY

imagined than answered. The words peaceful and law-abiding, are used advisedly ; in one quiet hamlet they were supposed to mark concealed magazines for storing explosives ; in another they were said to have been erected for the use of political orators with megaphones, that the ensuing general election might possess novel features, and incidentally tend to the glory and perpetuation of the Government of the day. The Press throughout the country has also contributed its quota to the general expression of interest ; but as a rule, the tone of press comments has been derisive.

It must be confessed that the task of endeavoring to make the story of the Geodetic Survey interesting, has been assumed with many misgivings. Nor is it to be expected that the huge interrogation mark resting upon the country at large can be straightened out by a single narrative, but it is hoped that a more sympathetic understanding may be aroused, so that in future the Departmental reports on this subject may receive more than casual notice ; and further, that the Survey may take its place beside other Public Works of accepted utility. There is another phase to Geodetic Surveys which is of absorbing interest to the scientific world, *viz.*, the necessity of an accurate knowledge of the exact size and figure of the earth. All astronomical computations, having for their object the determination of celestial distance, are based upon this knowledge — the accuracy of the determination of the movement of the heavenly bodies — the map of the heavens — depends upon the results of Geodetic Surveys based upon the science of Geodesy.

The original settlement, and establishment of homes in new countries is made possible by surveys defining the limits of the homesteads. Villages, towns and cities make their appearance in the wake of surveys, and thus surveys may claim to be the beginning of substantial progress in all countries. The development of public works such as canals, railways, roads and bridges has its origin in accurate surveys.

In Canada a systematic plan of survey was adopted during the last decade of the eighteenth century. In 1794 instructions

were issued to Deputy-Surveyor Stegman to survey the boundaries of certain townships in the vicinity of Ottawa, and to place monuments marking the limits of lots, fronting upon the Ottawa and Rideau Rivers, having an approximate area of two hundred acres each. The remaining portions of these townships were subsequently sub-divided by other surveyors; the maps and field notes of these surveys, and surveys of a similar nature all over Eastern Canada are the only official records of the size and form of our country. The measure of the accuracy of the surveys referred to is within the knowledge of the writer. In one locality near Ottawa a tract of land three-eighths of a mile wide, not included in the township surveys, was discovered quite recently, and in another township quite near the tract referred to, another fertile belt one-eighth of a mile wide has never been discovered officially. The existing maps of the older portions of Canada are compilations of surveys similar to those mentioned above. The expert knowledge and ingenuity of geographers have been taxed to their utmost in arranging by torsion the data at their disposal, so that many disturbing discrepancies might be reconciled as far as possible.

Since the formation of a permanent staff of astronomers in Canada the latitude and longitude of many points have been established by astronomical observations, these being subject to influences introducing an element of uncertainty which science cannot cope with except through the medium of a Geodetic Survey. For the purpose of maps of the scale commonly employed the observations referred to have been invaluable in view of the fact that the uncertainty of such observations is not of sufficient magnitude to be appreciable on maps of small scale.

The development of the natural resources of Canada has far outstripped her progress in some branches of scientific work; the necessity for accurate detail maps of the surface of the country has long been felt. The data for placing the parallels of latitude and meridians of longitude in their true places with reference to available surveys of the townships and lots, could be secured in no other way than by a Geodetic Survey.

All geodetic stations are connected by survey to the nearest township lot corner, in this way making the Geodetic Survey a basis for accurate skeleton maps on which may be placed the contours of the surface and all the geographical and physical information necessary to form maps containing information to aid materially in the commercial and strategical development of Canada. The accuracy of all future surveys for public works such as canals or railways or any other work requiring accurate surveys, may be checked absolutely by referring them to the nearest geodetic station as the work of such surveys progresses.

The foregoing may be considered as a general statement of the scope and object of the Geodetic Survey of Canada; the story of the work itself may be found more interesting.

The physical features of that portion of Canada extending from the westerly boundary of the State of Maine to the Detroit River and Lake Huron — the section to which the energies of the Geodetic Survey have been more particularly directed, may be briefly described as follows.

In the Province of Quebec, from the State of Maine to a line drawn due south from Rigaud, forty miles west of Montreal, the surface in the easterly section is rolling and hilly and in some sections mountainous, flattening out as the westerly limit mentioned is approached, but with isolated mountains rising more or less abruptly from the comparatively level plains. This district was found to be especially favorable for geodetic work; there are triangles in this section having sides eighty miles long.

From Rigaud, westerly throughout the remainder of the Province of Quebec and through southern and south-western Ontario to the Detroit River and Lake Huron, conditions were encountered that were most discouraging, and taxed to the utmost the skill and patience of those entrusted with the preliminary work of selecting the stations for the purpose of the survey. For long stretches the surface is slightly undulating with occasional stony ridges, usually old sea beaches, of no

decided elevation above the surrounding country. Between Lake Ontario, Lake Huron and Georgian Bay, the general surface gradually ascends by means of extensive transverse ridges which are themselves broken up into rolling and hilly surfaces until an elevation of seventeen hundred feet above sea level is attained in the vicinity of Dundalk.

The work of the survey is divided into the following branches, proceeding in the order noted ; reconnaissance, station building, observing and computing. The astronomical observations and the measuring of the base lines — the other branches of the work — may be introduced when deemed best for the progress of the survey.

RECONNAISSANCE

In the month of June, 1905, the work of the Geodetic Survey was commenced at Kingsmere, a short distance west of Chelsea, in the Province of Quebec. One of the three high elevations just north of Kingsmere Lake was visited on that date by the writer, and a careful study of the surrounding country made, having in view the selection of stations most suitable for the purpose of the survey.

The survey is spread over the country trigonometrically — in other words by means of triangles — starting from a measured base, having the angles of the triangles measured, and their sides computed by the aid of trigonometry, which may be briefly stated as the science of determining — in the case of the Geodetic Survey — the lengths of the two unknown sides of a triangle when one side and the angles have been measured. The triangles selected are combined to form four, five, six and even seven sided figures for more precise computation of distance. The angles of the triangles are measured by instruments of precision called theodolites, which are constructed with the greatest possible accuracy. When a theodolite is placed at one of the angular points of a triangles, it is essential that all the other angular points of all the triangle to which this point is common, are visible ; it is also essential that all the angles of

primary importance to the survey shall be more than thirty degrees. The above requirements must be fulfilled in the selection of the angular points — or stations — when the reconnaissance and preliminary survey is made.

In order that the intervisibility referred to may be secured it is necessary to erect skeleton towers on which the theodolite is mounted, a sufficient height above the ground to command the other stations to be observed. The determination of the heights of these towers is one of the duties of the officials conducting the reconnaissance survey.

Base lines are measured at intervals throughout the survey, and as these base lines are sides of triangles, forming part of the main chain of the survey — and all the angles of the triangles are measured — the computation of the lengths of all the sides of the triangles between the bases, seems to be a comparatively simple problem. When the magnitude of the triangles involved is considered — some of the sides exceeding eighty miles — elements are introduced which require most elaborate and exhaustive mathematical investigation.

Astronomical observations of latitude, longitude and azimuth are made at suitable stations, so that the geographical position of every station of the survey may be computed.

The selection of the angular points of the net-work of triangles is the beginning of the survey. Officials specially trained, and possessing instinctive knowledge of locality in its widest and most comprehensive sense are sent out to make an examination of the surface of the country to be covered. The highest points are visited, and from such points as are considered possible for stations, careful sketches of the horizon are made; the directions of all prominent elevations are referred to the astronomical meridian by means of observations on the the sun, or if the day is cloudy, to some known point located on the map used for this work. The survevor's outfit for reconnaissance consists of a small theodolite with vertical circle and magnetic needle, a good three-inch compass, a telescope, field glass and a pair of climbers similar to those used by telephone employees.

Many of the stations occupied are timbered and the observations must, therefore, be made from trees, and the work is carried on all the year round. Mounting an instrument on the sawed off trunk of a tree fifty or sixty feet from the ground — clinging to the side of the tree with the aid of climbing irons and making an exhaustive study of the horizon in a temperature many degrees below zero — with a wind: these conditions call for mental and physical qualities of no ordinary calibre. One assistant surveyor is allowed to each party. He records all observations and is usually selected on account of special qualifications for the work so that he may in time assume charge of a section of the reconnaissance survey.

At the close of the day, the stations occupied are marked on the map and lines radiating therefrom to other possible stations are plotted. As the work progresses the surveyor in charge becomes familiar in a general way with the trend of the culminating ridges — sometimes called the grain of the country — and can begin the formation of triangles, quadrilaterals and polygons. He then encounters the many difficulties due to the scientific requirements of the work. Certain lines are found to pass over cities, which makes them subject to local heat waves and smoke. Other lines graze the sides of timbered ridges, exposing them to lateral refraction which causes serious errors in the measured angles. The work of re-adjusting the figures to avoid these unfavorable conditions is undertaken. Other difficulties arise unexpectedly — perhaps one of the most important lines in a large figure is found to be closed, and another station or stations must be selected.

As the survey is extended and enlarged, the accumulation of obstacles and difficulties is most disheartening. The official in charge of the Geodetic Survey finds it necessary to visit these parties at intervals in order that these mountains of trouble may — to a certain extent — be made to appear less formidable.

The success of the survey is largely dependent upon the thoroughness of reconnaissance; especially in the country covered in Canada where the selection of figures of fixed mathe-

matical strength is impossible. There is no choice; it is a case of making the best possible use of the surface of a country which is not designed for Geodetic Surveys of ideal mathematial conditions. The applications of rules for determining strength of figures and limiting the field work to certain requirements based upon these rules would entail an expenditure similar to that of the construction of a railway from Calgary to Vancouver — in a straight line. The economic assimilation of theoretical and practical requirements is essential to success — perhaps to a greater extent in a Geodetic Survey than any other undertaking — as the computations involved drift naturally and by most attractive routes into refinements which are infinitely beyond the possible precision of the measurements of the magnitudes involved.

The work of reconnaissance is now in progress in advance of the other branches of the survey. The experience of the Canadian Survey with respect to this section of geodetic work has presented no new features, when compared with similar work in other countries. Perhaps an exception may be made with reference to carrying on the work in winter. On account of the scarcity of prominent elevations, and the prevalence of timber, the winter season has been found most suitable for reconnaissance in Canada. The absence of leaves from the trees and the covering of snow on the hill tops are invaluable in disclosing the irregularities of the horizon.

The completion of reconnaissance is followed by the preparation of the stations for their occupation by the large theodolites. After this is accomplished, and before the theodolite is used, the reconnaissance party examines the lines, testing them for intervisibility. Should any of the lines be closed the obstruction is located by survey and, if possible, removed. Should the obstruction amount to "grounding" the line, the whole figure involved must be revised and made possible by the insertion of one or more additional points. Many of the lines cannot be tested before the observing towers are erected. In 1910 a portable tower was devised which has proved a great assistance. It is in sections, three by twelve feet, arranged for bolting together for

the purpose of erection. Its form is triangular and its height eighty feet; eight wire cable guys are used to secure rigidity, and it has been exceedingly useful to the work.

STATION BUILDING

Following in the wake of the reconnaissance is a party of signal builders. Their work consists of the preparation of the stations for their occupation by the observing party. In the Province of Quebec and occasionally throughout Ontario, stations occur on mountain tops where no towers are necessary — except in special cases referred to subsequently. Such stations are marked by round copper bolts three quarters of an inch in diameter, the geodetic station being indicated by an eight-inch triangle cut in the rock around the bolt marking it. Three other bolts are placed in solid rock at convenient distances at the points of arrows, the shafts of which radiate from the station bolt. All the bolts are fastened into close fitting drill-holes so that their permanence is assured. The central bolt is stamped with a cross, the letters "G. S. C." and the year of location.

Stations in a hilly or undulating country cause more work in their preparation; skeleton towers from thirty to one hundred feet high become necessary in order that the other distant stations may be seen. These towers consist of a tripod surrounded by a scaffold to support the observer so that when a theodolite is mounted on the top of the tripod the observer may walk around his instrument without disturbing it.

The whole structure is designed and erected so as to obtain maximum rigidity with the minimum weight of timber, the latter varying in size from two by four to eight by eight inches according to the height of the tower. By renewing the footings, tightening the spikes and if necessary reinforcing the insides of the tripod legs, the efficiency of these towers can be maintained for a period of about ten years.

The construction of the towers is carried on by men especially adapted to the work; these men have continued with the survey from year to year since its inception. They are excellent

rough carpenters, and, at least, one of them must know how to take and compute an astronomical observation at any time during the day, as the tower legs must be placed clear of all the lines to be observed. The foreman of the tower building party revises reconnaissance, examines lines for intervisibility, makes the necessary surveys for finding obstructions, removes them; is in fact an official whose work is most varied and constantly in demand.

One side of the tripod and two sides of the scaffold are framed on the ground. A single post is so placed that it can be used for hoisting. With the aid of block and tackle and a pair of steady horses the side of the tripod is raised from the ground to an upright position,—the third leg of the tripod is then raised and attached to the other two by ties and diagonals. The completed tripod is used to raise the two sides of the scaffold framed on the ground. After these sides are raised they are connected by ties and diagonals, thus completing the structure.

The plots of ground on which the towers are erected are leased at a nominal rental for a term of ten years. The thanks of all the Officials of the Survey are due to the various owners of lands found necessary for the work, and the uniform courtesy and desire to assist in every way possible have added materially to the comfort of the men engaged in the work of the Survey.

Stations on hill-tops where towers are constructed are marked by an underground mark consisting of a copper bolt set in concrete in a drain tile on end, below the frost line, and also by a surface mark of a similar nature placed twelve inches under the top of the ground. In addition to the marks underneath the tower, a reference monument of artificial stone is erected—usually in the nearest fence line. It is five feet high, twelve inches square at the surface of the ground and nine inches square at the upper end, and is set in a concrete base three feet square and of sufficient depth to be secure from the action of frost. This monument is connected with one of the primary lines of the Survey and will eventually have a copper plate on its base, on

which will be marked its latitude and longitude. In the years to come -- after the towers have been removed -- these monuments will form the visible marks of the Survey. The underground marks will remain for the purpose of triangulation surveys in the future.

OBSERVING

The preparation of the stations for their occupation by the observing party is followed by the measurement of the angles by the surveyor in charge of that branch of the work.

The precision of geodetic surveys has always, to a large extent, been limited to the degree of perfection attained in the construction of theodolites. Geodesists in charge of the surveys conducted on various portions of the globe for more than a century have contributed their quota to the form of these instruments. Thus so many different ideas have been embodied in their design that it is questionable whether in their essentials the theodolites of to-day are any improvement upon those made by Ramsden in the eighteenth century. Unfortunately the desire for trivial conveniences which add to physical comfort has absorbed the attention of many observers, at the expense of more substantial improvements.

An instrument which is expected to be free from many of the imperfections of those now in use has been designed for the Canadian Survey, and its success is earnestly hoped for by other countries as well as Canada.

A geodetic theodolite consists essentially of two parts, a graduated horizontal circle and a telescope constructed to revolve on a centre common to both ; there are also micrometer microscopes turning with the telescope in a plane parallel to that of the graduated circle. The circle can be moved around the common centre and clamped in any position leaving the telescope and its accompanying microscopes free to turn from point to point around the horizon. As each successive pointing on objects connected with the survey is made, the micrometer microscopes focussed on the graduated circle are read. The differ-

ences between these readings is the measure of the angle -- in degrees, minutes and seconds -- between the points to which the telescope has been directed.

Of the various parts of a theodolite, the graduated circle is probably the most important. For modern geodetic work the diameter of the graduated portion is usually twelve inches, but circles thirty-six inches in diameter have been used. The circle is divided into four thousand three hundred and twenty parts, each covering five minutes of arc. The spaces are defined by fine marks on silver : excluding the widths of the marks each space covers less than one-hundredth of an inch. An error of one seventeen thousand of an inch in marking one of these lines would mean two seconds of arc or a horizontal displacement of six-tenths of an inch at a distance of one mile. The graduating marks are made by a sharp tool held nearly vertical, controlled automatically by a complicated engine made with the greatest precision. Provided all the frictional parts are free from appreciable dust particles, that all the sections of the engine, the plate itself and the atmosphere in the room, are at the same temperature and remain so throughout the period of graduation, and that no controlling surface of the mechanical parts has become worn, the operator may expect success to crown his efforts. However, notwithstanding the supposed perfection of modern graduating engines, errors of from five to eleven seconds have been found in instruments in use in Canada.

All the parts of a theodolite should contract and expand uniformly during changes of temperature and yet the material used in construction must be hard enough to resist friction at many bearing surfaces. Various alloys have been utilized but unfortunately all alloys of metals are subject to molecular action which may distort, lengthen or contract the mass while aging is in progress.

In order that the fine marks on the circles of the theodolites may be accurately observed by the micrometer microscope referred to, their magnifying power must be high and the lenses

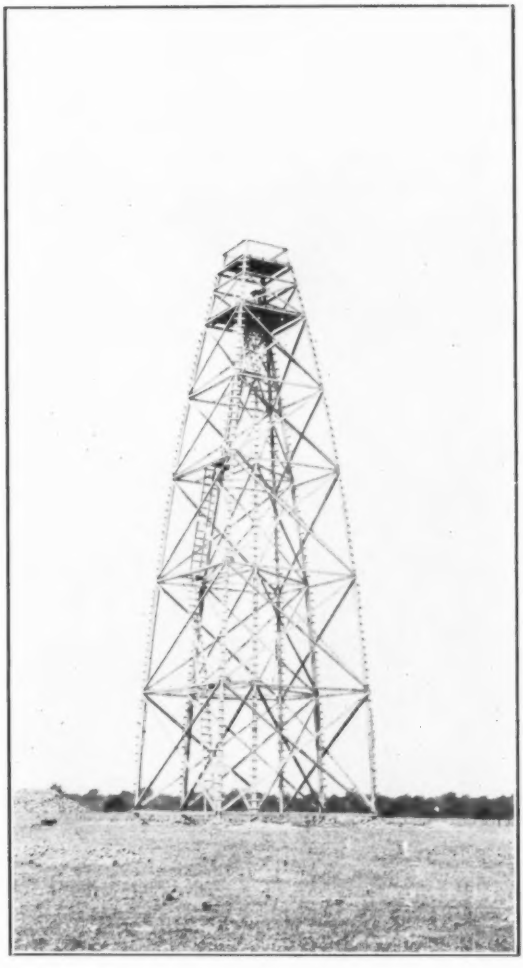
of good quality. This results in sharp focussing, and the slightest change in focal distance causes the marks to disappear. The molecular changes referred to in the above paragraph, have distorted one of the circles now in use in Canada to such an extent that as the micrometers are revolved the graduations upon a certain section are appreciably out of focus. In the case of the circle referred to, the change appears to be a function of the temperature. In the Great Triangulation of India, the same difficulty has been encountered to a more serious extent than in Canada, perhaps on account of the higher temperatures experienced.

All branches of science depending upon mechanical measurements for their practical development encounter all manner of discouraging obstacles, the desire to attain a degree of refinement beyond a certain limit seems to challenge an array of trouble that is beyond conception. Geodetic surveys have always received especial attention of this nature. The instance of the graduated circle has been introduced as an example of what may be expected when one attempts to cross the boundary between ordinary and precise measurements.

An observing party, for observing horizontal angles, consists of a surveyor, a recorder, a cook and five or six light-keepers. The light-keepers are sent to the stations surrounding the one to be occupied. They show a light on the top of the tower from a point over the centre of the tripod which is also vertical to the station mark in the ground. In the daytime the light consists of a beam from the sun reflected along the line by means of mirrors; at night an acetylene gas lamp is used.

The surveyor measures the angles in succession around the horizon beginning at a station called initial. The telescope is directed to this station and after the micrometer microscopes are read the telescope is turned to the right until the next station is intersected. The microscopes are again read, and so on in succession until the initial station is again reached and read upon; the instrument is then reversed and another series of readings is made around the circle to the left. The two rounds of

PLATE XXXV.



OBSERVING TOWER
CANADIAN GEODETIC SURVEY

readings constitutes a determination of the angles, and sixteen determinations are made starting from as many different points on the graduated circle. The instrument is reversed between the rounds to correct certain defects in construction and adjustment; the direction of the round is changed to annul the effect of twisting of the tripod due to unequal heating and cooling of the timber of which it is constructed. The circle is moved in order that the readings may be spread over the graduations symmetrically, eliminating as nearly as possible the errors of spacing referred to in a previous paragraph. It may be said briefly that the whole system of measuring angles, or using instruments of precision for any purpose whatever, is designed to meet and, as far as possible, counteract the effects of their mechanical imperfections. After every known precaution is taken, there is always the knowledge that atmospheric conditions and changes must be encountered and these are so subtle and uncertain in their action that the work of an observer is no sinecure. The successful accomplishment of work of this nature within certain limits of precision which are fixed, is impossible to the careless and indifferent observer. From the time the first pointing is made until the night's work is finished the physical and mental strain is never relaxed. Each day and night brings its own atmospheric combinations; the various parts of the instrument are never at rest; at any moment something may occur which might destroy the accuracy of a night's work or, if not fatal, may introduce irregularities that harrow the nerves of the man at the eye-pieces. But in spite of this there are many compensations for an observer whose heart is in his work; he can derive a large measure of unalloyed pleasure from results that are entirely satisfactory. In addition to the measurement of horizontal angles angular distance from the zenith to all stations around the one occupied is also observed, in order that their relative elevations above sea-level may be computed. The datum of sea-level is obtained through connection with geodetic levels at points throughout the survey.

COMPUTING

The work in the field is followed by the office computations which begin at the primary base line and are carried through all the triangles to the next base, determining the lengths of all the sides, their astronomical azimuths — or courses — and the latitude and longitude of the angular points.

In connection with the work in the field the measure of accuracy is indicated by certain geometrical conditions which should be satisfied: *viz.*, the sum of all the angles measured around the horizon at a station, closing the circle, should be three hundred and sixty degrees, and the sum of the three angles of each triangle should be one hundred and eighty degrees plus the spherical excess.

The triangles of a Geodetic Survey are so large that the spherical form of the earth must be taken into consideration. The angles at the three angles of the triangles, are the angles of inclination of planes which intersect near the centre of the earth and are, therefore, in excess of three right angles. The amount of this excess in a given latitude is proportional to the areas of the triangles. This very casual statement of the theory of spherical triangles is sufficient for the purpose of this paper; it explains the means at the disposal of the surveyor in the field for checking the work as it proceeds.

On account of the imperfection of theodolites, and many other adverse conditions met with in measuring the angles, the results do not satisfy the geometrical requirements; the sums of the angles measured around the horizon are not equal to three hundred and sixty degrees, and the sums of the three angles of the triangles are not equal to two right angles plus the spherical excess. With reference to the latter requirement, the Geodetic Survey of Canada has adopted the standard of one second of arc as the average summation error allowable. With regard to the error of closure of the circle, the instructions issued to observers of horizontal angles do not allow any latitude beyond the probable error of the determination of the angles.

The principal work of the computing staff consists of the adjustment of the triangles, which are combined, forming figures which are most convenient for the determination of the small errors of closure.

All precise work having for its object the measurement of small magnitudes is subject to error, even if mechanical adjuncts were perfect and there were no adverse conditions of atmosphere or temperature, personal error would have to be reckoned with. After every known precaution has been used, the writer is of the opinion that in astronomical and geodetic work, error due to uncompensated personal equation still exists. As a simple illustration of this statement the observations on a signal light may be used.

The days when observations are possible are not of frequent occurrence. An observer commences work at three o'clock in the afternoon. His observations are made by adjusting his telescope so that the spider lines intersect an image consisting of rays of light which come from a mirror, perhaps, forty or fifty miles distant. Owing to intervening physical conditions the atmosphere is boiling, and the rays of light are, in addition to uncertain flashing, gyrating over a large portion of the field of view of the telescope. For the purpose of this class of work two vertical spider lines are used; the observer watches the movements of the signal light, at the same time adjusting the telescope until the flashings are apparently covering equal areas outside of the vertical lines. The next signal to which the telescope is directed is probably thirty miles from the first and only twenty from the observer. In the meantime clouds may have drifted across a portion of the second line and the signal light looks like a first magnitude star; and so on around the circle, no two images alike. At night an entirely different image is seen, that of an acetylene lamp observed in a telescope illuminated artificially. As the day and night progresses the physical and nervous strain becomes evident — some of the pointings are made with less care, or even with equal care but impaired judg-

ment, and the work between three and four o'clock in the afternoon and between one and two o'clock in the morning may be expected to be appreciably different.

It is assumed that all observations are in error and that if a triangle closes without any indicated error, the apparent perfection of the work is due to accidental compensation. The adjustment of the triangles and their figure combinations consists of a distribution of the errors of closure which is accomplished by means of the method of least squares; in other words the corrections applied to the angles of a figure are such that the sum of their squares is a minimum.

The figure adjustment is followed by the computations of the lengths of the sides; and of the differences of latitude, longitude and azimuth, from station to station throughout.

ASTRONOMICAL OBSERVATIONS

The accuracy of all astronomical observations is to a large extent dependent upon spirit levels, which are supposed to indicate the direction of a horizontal plane. Unfortunately they are influenced by the unequal distribution of gravity and the uncertainty of the results of astronomical observations referred to in a previous paragraph is due to this influence. The variation of gravity is caused by the unequal density of the earth's crust and by inequalities on its surface. If the uncertain results were in proportion to the visible mass, the computation with the contour of the surface as data would be comparatively simple, but the actual variations of instrumental results are at some places on the surface of the earth in opposition to that theory (See *Philosophical Transactions*, 1855-59). In the vicinity of Moscow on a comparatively level plain, the variation amount to sixteen seconds of arc in sixteen miles: that is to say, astronomical observations for latitude on the same meridian at two points sixteen miles apart would indicate that the points were sixteen miles and sixteen hundred and seven feet apart, an error of nearly one-third of a mile. A geodetic survey enables astronomers to make their computation with reference to the relative latitude

and longitude of the stations of the survey with certainty; and astronomical observations at a number of stations throughout the survey will furnish a mean astronomical datum which will be sufficiently near the truth to satisfy the scientific requirements of the survey. This branch of the work is of absorbing interest. It deals with a subject that would furnish most interesting material for discussion but the time at our disposal does not admit of more than passing notice.

GENERAL REMARKS

Owing to the delay in starting a Geodetic Survey in Canada, the demand for its existence has arisen in isolated provinces causing a distribution of the work to meet as nearly as possible the requirements of the country. Geological Surveys in the Maritime Provinces; International Boundary Surveys west of Lake Superior and the rapid development of British Columbia; have demanded immediate attention. The more thickly populated Provinces of Ontario and Quebec are now being mapped topographically, requiring the angular points of the Geodetic Survey for the purpose of the projection of the maps.

The triangulation has been completed over the following areas: the Provinces of Nova Scotia and New Brunswick, three thousand eight hundred and forty square miles; Quebec and Ontario, thirty-four thousand three hundred and thirty and in British Columbia, one thousand four hundred and thirty square miles. Observing stations have been prepared for the further extension of the survey over two thousand two hundred and fifty square miles in Nova Scotia and New Brunswick, fifteen thousand and ninety square miles in Ontario and one thousand four hundred and thirty square miles in British Columbia.

Reconnaissance surveys have been extended over an area of twenty-seven thousand five hundred square miles in the Provinces of Nova Scotia, New Brunswick, Ontario and British Columbia.

In addition to primary triangulation for the purpose of the Geodetic Survey, spirit levelling of the highest order of precision

has been in progress since nineteen hundred and seven; two thousand six hundred and twenty-seven miles have been completed in the Provinces of Nova Scotia, New Brunswick, Quebec and Ontario. The limit of error allowed is 0″·017 M; "M" being the distance in miles. The only circuit closed is four hundred and twenty-one miles long; the indicated error is 0″·16; less than one half the error allowable.

DOMINION OBSERVATORY,
OTTAWA, CANADA.
October, 1912.

THE ORBIT OF β CORONÆ BOREALIS

By J. B. Cannon

THIS star has been under observation here during the years 1910-12. It was first announced as a binary by Mr. Moore in *L.O.B.* IV, 162, from eight measures giving a range from – 16 to – 33 kms. The observations here show a range of approximately the same magnitude. The errors of measurement were, however, considered so large that it was doubted whether any orbit could be determined. For a time micrometer measures were made but the uncertainty of the wave-lengths of the better lines led to the abandonment of this method. A solar standard was then used in measuring a few plates on the Zeiss Comparator, but the lines in the sun and in the star were so different that the results were very unreliable. Finally, a wide spectrum of the star itself was obtained and used as the standard in the measurement of all the plates and these measures were taken as fairly reliable. The standard used was plate number 4330. The velocity of the standard was determined by micrometer measurement and also by measuring on the Zeiss Comparator against a solar standard. The mean, – 18·6 km., was accepted as the velocity of the plate. If this varies to any extent from the true value, it makes no difference to the form of the orbit, but only alters the postion of the γ line.

One hundred and fifty-three plates were taken and measured but even with this large number of observations the results did not at once promise the finding of any period of oscillation. However, plotting the observations consecutively gave an indication of a period of about forty days. When further work had been done it was found that 40·9 days fitted the observations as a whole, perhaps, better than any other. This consecutive plotting of observations further showed that the maximum in the

various oscillations did not reach the same velocity, but varied to the extent of about 4·8 km.; and showed also that a certain value of the maximum was repeated in about twelve periods or 490·8 days. This seemed to indicate a three body system, the body which gives the spectrum measured revolving about another in 40·9 days, and the two, with a third, forming a period of perturbation of 490·8 days. A sine curve was assumed for the long oscillation and the values given by it applied to the velocities obtained from the different plates. In order to get a curve for the short period and to use all the observations in the determination of this curve, a standard maximum was adopted at − 16·8 km., and the various periods reduced to this standard by adding or subtracting as the case might be. The sine curve mentioned above was taken with an amplitude of 4·8 km., its up-curve crossing the zero line at Julian Day 2,418,804·4 and its maximum being + 3·2 km., and its minimum, − 1·6 km. The various values given by this were read off and added to the velocity given by each plate. This very much improved the state of affairs and when the observations were plotted with these corrections the form of the curve was clearly seen, although it must be admitted that some of the residuals were rather large.

Observations are given in Table I.

TABLE I.

OBSERVATIONS OF β CORONÆ BOREALIS

Plate	Julian Day	Phase	V	Correction for third body	V′	Residual
3220 f 3221 s	2,418,726·93	28·54	− 24·5	− 1·6	26·1	− 3·9
3302 f 3303 s	740·89	1·60	− 22·8	− 1·4	− 24·2	2·6
3384	773·80	34·51	− 30·0	− 0·8	− 30·8	− 6·4
3389	774·85	35·56	− 25·3	− 0·8	26·1	− 1·6
3413 f 3414 s	789·80	9·61	− 27·9	− 0·4	28·3	− 9·4
3421	796·77	16·58	− 29·6	− 0·2	− 29·8	− 10·1
3486	841·68	19·79	− 21·8	+ 1·2	− 20·6	− 0·3
3502	852·73	31·64	− 25·7	+ 1·4	− 24·3	1·0
3514	859·70	38·61	− 27·4	+ 1·6	− 25·8	0·9
3595	913·58	10·69	− 21·5	+ 2·8	− 18·7	+ 0·3
3628 f 3629 s	924·52	21·63	− 17·5	+ 3·0	− 14·5	+ 6·1
4027 f 4028 s	9,095·87	29·38	− 22·1	+ 0·3	− 21·8	+ 0·4
4065	102·80	36·40	− 22·9	+ 0·1	− 22·8	+ 1·9
4075	103·90	37·41	− 30·2	+ 0·1	30·1	− 5·3
4084 f 4085 s	104·83	38·34	− 25·8	± 0·0	25·8	0·8
4097	106·94	40·45	− 23·2	± 0·0	− 23·2	+ 0·8
4127	112·94	5·55	− 17·6	− 0·2	− 17·8	+ 1·3
4149 f 4150 s	124·90	17·51	− 22·4	− 0·5	− 22·9	3·0
4160 f 4161 s	129·83	22·50	− 20·5	− 0·6	− 21·1	0·3
4166 f 4167 s	131·84	23·46	− 23·0	− 0·6	− 23·6	− 2·6
4184	137·90	30·51	− 21·6	− 0·8	− 22·4	+ 0·4
4192 f 4193 s	138·84	31·45	− 26·1	− 0·8	− 26·9	3·8
4199	144·76	37·37	− 26·0	1·0	− 27·0	− 2·0
4209 f 4210 s	145·88	38·49	− 27·2	− 1·0	− 28·2	3·2
4224	147·79	40·40	− 22·9	1·0	− 23·9	+ 0·1
4243 f 4244 s	150·77	2·48	− 28·0	1·1	− 29·1	− 8·5
4261 f 4262 s	152·83	4·54	− 27·0	− 1·1	28·1	− 8·7
4268 f 4269 s	153·82	5·53	− 15·6	1·1	16·7	+ 2·4
4276 f 4277 s	155·74	7·45	− 23·5	− 1·2	− 24·7	− 5·8
4297 f 4298 s	162·76	14·47	− 21·0	− 1·3	− 22·3	− 2·9
4313 f 4314 s	176·80	28·51	− 20·5	1.4	− 21·9	0·3
4316 f 4317 s	178·80	30·51	− 23·7	1·5	− 25·2	2·4

TABLE I.—(*Continued*).

Plate	Julian Date	Phase	V	Correction for third body	V'	Residuals
4321 f 4322 s	2,419,182·66	34·37	− 27·4	−· 1·5	− 28·9	− 4·7
4334 f 4335 s	186·76	38·47	− 23·8	− 1·6	− 25·4	− 0·4
4339 f 4340 s	187·76	39·47	− 24·5	− 1·6	− 26·1	− 1·5
4345 f 4346 s	189·72	0·53	− 20·8	− 1·6	− 22·4	+ 0·4
4353	190·72	1·53	− 19·3	− 1·6	− 20·9	+ 0·8
4363 f 4364 s	197·64	8·45	− 15·8	− 1·6	− 17·4	+ 1·4
4369 f 4370 s	204·72	16·53	− 14·6	− 1·6	− 16·2	+ 3·4
4375 f 4376 s	208·63	19·44	− 19·0	− 1·6	− 20·6	− 0·4
4379 f 4380 s	210·62	21·43	− 19·0	− 1·6	− 20·6	± 0·0
4383 f 4384 s	211·65	22·46	− 19·8	− 1·6	− 21·4	− 0·6
4392 f 4393 s	216·64	27·45	− 15·2	− 1·5	− 16·7	+ 5·2
4394 f 4395 s	217·58	28·39	− 21·9	− 1·5	− 23·4	− 1·2
4402 f 4403 s	218·67	29·48	− 19·4	− 1·5	− 20·9	+ 1·6
4406 f 4407 s	221·63	32·44	− 13·3	− 1·5	− 14·8	+ 8·7
4415	224·59	35·40	− 18·1	− 1·4	− 19·5	+ 5·0
4424	230·56	0·47	− 15·3	− 1·4	− 16·7	+ 0·2
4432	232·62	2·53	− 11·1	− 1·4	− 12·5	+ 8·1
4433 f 4434 s	236·57	6·38	− 21·5	− 1·3	− 22·8	− 3·8
4439	238·57	8·48	− 15·0	− 1·3	− 16·3	+ 2·5
4442 f 4443 s	239·56	9·47	− 21·0	− 1·2	− 22·2	− 3·4
4449 f 4450 s	242·68	12·57	− 17·9	− 1·2	− 19·1	± 0·0
4486 f 4487 s	263·55	33·46	− 19·6	− 0·8	− 20·4	+ 3·4
4898 f 4899 s	480·86	5·37	− 18·8	+ 3·0	− 15·8	+ 3·3
4911 f 4912 s	484·82	9·33	− 30·8	+ 3·0	− 27·8	− 9·0
4919 f 4920 s	487·83	12·34	− 23·4	+ 2·9	− 20·5	− 1·4
4927 f 4928 s	491·85	16·36	− 20·6	+ 2·8	− 17·8	+ 1·8
4931 f 4932 s	493·78	18·29	− 26·8	+ 2·8	− 24·0	− 4·0
4937 f 4938 s	496·81	21·32	− 26·0	+ 2·7	− 23·3	− 2·7

TABLE I.—(*Continued*).

Plate	Julian Day	Phase	V	Correction for third body	V′	Residual
4950 / 4951 \	2,419,504·82	29·33	− 27·8	+ 2·6	25·2	− 2·8
4956 / 4957 \	505·79	30·30	− 23·6	+ 2·5	23·1	+ 1·7
4961	509·87	34·38	− 22·0	+ 2·4	19·6	+ 4·0
4969	512·78	37·29	− 28·1	+ 2·4	25·7	− 0·8
4973 / 4974 \	513·74	38·25	− 29·8	+ 2·4	27·4	− 2·4
4980 / 4981 \	516·80	0·39	− 21·1	+ 2·3	18·8	+ 4·3
4984 / 4985 \	518·77	2·38	− 17·9	+ 2·3	15·6	+ 5·3
4988	520·77	4·38	− 21·9	+ 2·2	19·7	− 0·8
4990 / 4991 \	522·77	6·38	− 14·3	+ 2·2	12·1	+ 6·8
4996 / 4997 \	523·80	7·41	− 19·9	+ 2·1	17·8	+ 1·1
5001 / 5002 \	525·76	9·37	− 14·6	+ 2·1	12·5	+ 6·3
5007 / 5008 \	526·76	10·37	− 20·6	+ 2·0	18·6	+ 0·3
5011 / 5012 \	533·79	17·40	− 19·6	+ 1·9	17·7	+ 2·1
5016	537·70	21·31	− 19·5	+ 1·8	17·7	+ 2·8
5018 / 5019 \	538·68	22·29	− 25·0	+ 1·7	23·3	− 2·5
5023	546·62	31·23	− 17·1	+ 1·5	15·6	+ 7·4
5027 / 5028 \	554·70	39·31	− 17·9	+ 1·2	16·7	+ 8·1
5032	559·64	3·31	− 15·2	+ 1·1	− 14·1	+ 5·9
5035 / 5036 \	560·69	4·40	− 20·3	+ 1·1	− 19·2	+ 0·3
5041 / 5042 \	561·74	5·45	− 26·2	+ 1·0	− 25·2	− 6·1
5049 / 5050 \	567·74	11·45	− 21·0	+ 0·9	− 20·1	− 1·1
5054 / 5055 \	571·61	15·32	− 19·6	+ 0·8	− 18·8	+ 0·7
5058	572·73	16·44	− 16·9	+ 0·7	− 16·2	+ 3·4
5062	575·67	19·38	− 18·9	+ 0·6	− 18·3	+ 1·9
5064	578·68	22·39	− 19·6	+ 0·6	− 19·0	+ 1·8
5069	579·70	23·41	− 22·4	+ 0·5	− 21·9	− 0·9
5071 / 5072 \	580·60	24·31	− 21·5	+ 0·5	− 21·0	+ 0·2
5086 / 5087 \	586·66	30·37	− 21·6	+ 0·3	− 21·3	+ 1·5
5091 / 5092 \	587·67	31·38	− 20·2	+ 0·3	− 19·9	+ 3·2
5111 / 5112 \	601·58	4·39	− 14·4	− 0·1	− 14·5	+ 5·0
5121 / 5122 \	607·61	10·42	− 14·1	− 0·3	− 14·4	+ 4·5

The observations were divided into fourteen groups and the mean phases and velocities computed. (See Table II.).

TABLE II.

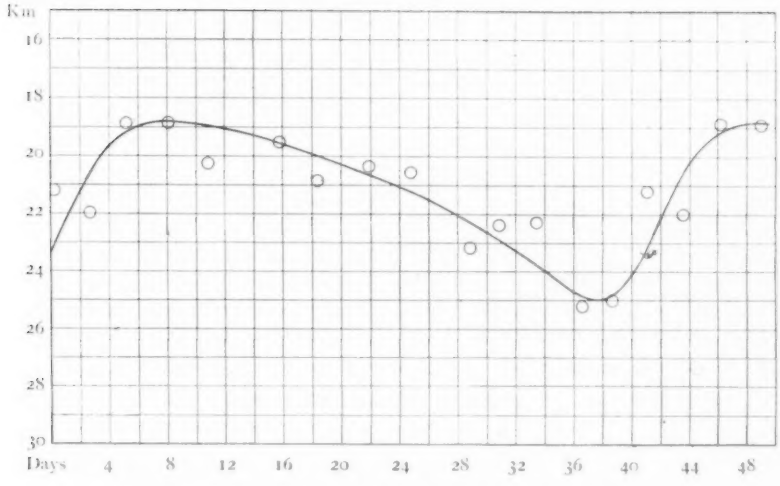
NORMAL PLACES

No.	Julian Day	Phase	Velocity	Weight	Residual O − C
1	2,419,156·78	28·94	− 23·20	2	− 0·86
2	348·67	30·87	− 22·40	2	+ 0·53
3	203·67	33·68	− 22·30	1	+ 1·58
4	143·96	36·57	− 25·20	1	− 0·33
5	249·77	38·71	− 25·00	2	− 0·09
6	271·19	0·23	− 21·20	1	+ 2·00
7	191·77	2·68	− 22·00	2	− 1·40
8	416·01	5·23	− 18·90	2	+ 0·30
9	389·20	8·09	− 18·90	2	− 0·10
10	322·50	10·87	− 20·30	2·5	− 1·38
11	223·14	15·85	− 19·60	2	− 0·05
12	213·95	18·44	− 20·90	2	− 0·92
13	295·77	21·93	− 20·40	2	− 0·33
14	347·84	24·83	− 20·60	1	+ 0·68

These fourteen normals were plotted and a curve determined graphically which fitted them very satisfactorily. This was as far as the work was carried, as it was not considered that the results arrived at were sufficiently definite to authorize an attempt at greater exactness in the final values of the elements of the curve. First, the accuracy of the measures, considering the small total range, cannot be taken as very great. Second, the sine curve of the third body with which the bright body and its companion form the long period oscillation cannot be considered very well defined. So that although these measures and the curve given by the third body seem to be the best so far obtainable, it would take many more observations and very close measuring to enable one to assert definitely that this is the true condition of affairs existing in the system.

The elements of the curve are :

P = 40·9 days.
e = ·4
ω = 240°
T = 2,418,739·29 J. D.
K = 3·10 km.
γ = − 21·28 km.
$a \sin i$ = 1,600,000 km.



VELOCITY CURVE OF β CORONÆ BOREALIS

The probable error of an average observation was computed to be + 2·6 km. and of an average normal place + 0·63 km.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
September, 1912.

MEETINGS OF THE SOCIETY

At Toronto.

October 8, 1912.— The meeting was held in the Society's Rooms, 198 College Street, President L. B. Stewart occupied the chair.

The meeting was devoted to reports by the members on observations made during the summer months.

The President gave an interesting account of observations taken in the past summer during work in the Hudson Bay region. By means of observations on the sun the geographical position of various points and determination of time for the various out-lying posts were made. He also gave a short account of the weather condition which prevailed, discussing the rainfall, winds, presence of ice, etc. He also spoke of the objects and personnel of the expedition and promised to give a fuller account of his experiences at a later date.

Mr. J. R. Collins gave a very interesting account of observations by himself and others on "Actual displacements of the several planets amongst the stars during the summer months."

Reference was made to the eclipse of the sun of April last and the results which have just come to hand; also to Nova Geminorum and the ephemeris of Gale's Comet.

Mention was also made of the rotation period of the planet Uranus as spectroscopically determined by Lowell, namely, 10 hours 50 minutes. The pole of the planet was pointing directly towards the earth in 1909 and it is only lately that it has shifted sufficiently to allow of this method of determination being used.

Professor Chant gave a short account of observations in the Georgian Bay district on Jupiter's moons, with the aid of field-glasses; also a brief sketch of the work of Poincaré, whose death took place recently.

October 22.—The following, who had been nominated at a previous meeting, were duly elected members of the Society:

Miss A. Elvira Falls, 318 Brunswick Ave., Toronto.

Mr. C. S. MacCulley, 79 Margueretta St., Toronto.

Mr. W. Whitney, 83 Grenville St., Toronto.

Mr. Chas. McAteer, Sacramento St., Pittsburgh.

Mr. J. P. McMahon, 821 Fifty-Fourth St., Pittsburgh.

Under Observations the ephemeris of Gate's comet was read and a note from Harvard College Observatory *Bulletin*, to the effect that the expedition in Brazil which had been stationed there to observe the total eclipse of the sun on October 10th, had reported the one word "rain," indicating that observations had been interfered with by unfavorable weather.

The President made some few remarks in reference to the climatic conditions prevailing in the region of Hudson's Bay, from which locality he had just returned. As at this time that region is demanding considerable attention the hope was expressed that he would see his way clear to give us a fuller account of the expedition at a future meeting. The paper for the evening was by Mr H. B. Collier, on "Meteorites"

The lecturer, with the aid of the lantern, described the various characteristic structures and composition of these celesial visitants and discussed the theories in regard to their formation and origin. A number of beautiful lantern slides were shown illustrating the most unsual formations.

An interesting discussion followed the reading of the paper participated in by a number of the members.

November 5.—In the absence of the President, Mr. W. B. Musson occupied the chair.

The paper for the evening was by Professor DeLury, on "The Life and Work of Poincaré." The intellectual develope-

ment of the great mathematician and mathematical astronomer of France, was interestingly traced by the lecturer, from his infancy to his maturer years and the great problems with which his name is associated were named and the manner and method of the great aid he has rendered to Astronomical Science, were lucidly explained.

An interesting discussion followed the reading of the paper. The paper appears in the present number of the JOURNAL.

November 19.—In the absence of the President, Professor C. A. Chant was appointed to the chair.

Mr. J. R. Collins gave reports of observations on Saturn, the drift of spots on the solar surface, the recently discovered comet showing the elements of Tuttle's Comet of 1858. Mr. Mason asked as to the effect of light pressure on the motion of comets. Professor Chant pointed out the exactness of the calculations of the orbits of planets without this effect being considered.

Mr. A. F. Miller gave the paper of the evening on "The Observatories of Greenwich and Paris," which he had visited during the past summer. Greenwich was first established as an aid to navigation. The necessity for observation in reference to winds, weather, and the means of getting correct longitude and latitude was presented. The method of determining positions was first put forward by Galileo and predictions made from observations on astronomical bodies, *e. g.* eclipses, position of the moon, etc. The earlier observations were made with very crude instruments, and to make considerable improvement in this respect, a building, designed by Sir Christopher Wren, was erected at Greenwich for Flamsteed, the first Astronomer Royal.

Slides showing the instruments at the two Observatories at the present time were shown, and a very interesting description of these instruments and the work being done at the Observatories was given by the speaker.

December 3.—Mr. J. R. Collins gave an account of observations made in Texas upon the great red spot of Jupiter, which

had maintained the same appearance for many years but is now showing unusual disturbance ; also of papers on the presence of radium in the chromosphere of the sun by Evershed and Mitchell, written in criticism of the paper by Professor Dyson, which had been referred to at a former meeting.

The paper for the evening was by Professor L. B. Stewart, on "A Recent Trip to the Hudson Bay District."

A map of the district was shown, and the speaker gave a brief outline of the course of the trip, together with its difficulties and interesting features. Views of Norway House were shown, and a description given of the customs and habits of the Indians and the work carried on at the fort. Views were also shown of York Factory, Fort Nelson, and the camp of the surveying party in several places, with a description of the work carried out by Mr. J. B. Tyrrell who was in charge of the expedition, and the speaker.

At the conclusion of the lecture many questions relating to the trip and the country were asked by the members and answered very fully and satisfactorily by Professor Stewart.

L. G.

At Ottawa

PROGRAMME FOR FALL TERM

October 10th, 3 p.m.—"The Geodetic Survey of Canada."—Charles A. Bigger, D.L.S., C.E., Etc.

October 24th, 8 p.m.—"The Story of the Pleiades."—W. E. Harper, M.A.

November 7th, 3 p.m.—"Programme of Work at the Yerkes Observatory."—R. M. Motherwell.

November 21st, 8 p.m.—"The Limits of Knowledge."—A. McGill, LL.D., F.R.S.C., Etc.

December 5th, 3 p.m.—"Transit Observations in 1910.—R. M. Stewart, M.A.

December 19th, 8 p.m.—Annual Meeting.

October 10, 3 p.m.— At the first meeting of the fall term, held at the Dominion Observatory, a paper on "The Geodetic Survey of Canada," by Charles A. Bigger, D.L.S., C.E., Etc., was presented by U. W. Christie, B.A.Sc., D.L.S., who, on

account of the enforced absence of Mr. Bigger, kindly consented to read the paper, illustrating it by diagrams and models.

Mr. Bigger introduced his subject with a few general remarks on the scope and object of the Survey. He showed clearly that the only way to secure an accurate topographical or contour map of an extensive area is by connecting the detail surveys with geodetic stations as frequently as possible. An accurate knowledge of the size and figure of the earth is useful in astronomical computations having for their object the determination of celestial distance.

The work of the Survey is divided into the following branches proceeding in the order noted: Reconnaissance, Station Building, Observing and Computing; while the Astronomical Observations and the Measuring of the Base Lines — the other branches of the work — may be introduced when deemed best for the progress of the Survey.

A reconnaissance survey was begun in June, 1905, by the writer's making a careful study of the country west of Chelsea in the Province of Quebec.

The Survey is spread over the country trigonometrically. The triangles selected are combined to form four, five, six and even seven-sided figures, care being taken that the angles of primary importance be more than thirty degrees. To secure the intervisibility of stations it is often necessary to fell trees and to erect towers of considerable height. These towers are double, having a tripod to support the instrument and a scaffold, separate from the tripod, on which the observer stands. Great stress was placed upon the fact that it is necessary to have a good instrument for measuring angles. This instrument, called a theodolite, has a graduated circle generally twelve inches in diameter having micrometers for reading the angles. The surveyor measures the angles in succession around the horizon, beginning at a station called "initial"; the telescope is directed to this station and after the micrometers are read it is turned to the right until the next station is interesected and read upon, and so on in succession until the initial station is reached and

re-read. The instrument is then reversed and another series of readings are made to the left. The whole system of measuring angles is arranged to meet and, as far as possible, to counteract the effect of mechanical imperfections. After every known precaution has been taken the writer is of the opinion that uncompensated personal errors still exist.

The field work is followed by an elaborate and complete least square computation in the office.

The paper appears in the present issue of the JOURNAL.

October 24th, 8 p.m.— The second meeting of autumn term was held at the Dominion Observatory. Mr. J. S. Plaskett presiding. The minutes of the last meeting were read and approved. Mr. Charles A. Bowman, Ottawa, and Dr. W. R. Greene, Ottawa, proposed at the last meeting were duly elected members of the Society. The chairman then called upon Mr. W. E. Harper, M.A., to give the address of the evening on "The Story of the Pleiades."

The subject was introduced by the lecturer's telling of the universal interest which the Pleiades had aroused in the past ages as evidenced by the numerous references to this group in the records of almost all nations, the traditions of many tribes associating disaster with the midnight culmination of the constellation in November. By means of sketches the relative positions of the brighter stars were shown and their names and brightnesses tabulated. It was shown how by counting the number of stars visible to the unaided eye in this convenient group the eye-sight or the seeing conditions could be tested. The name of the constellation was probably derived from one of the three Greek words, meaning "a flight of doves," "to sail" and "full" or "many," preference being given to the latter.

The story was narrated of the "Lost Pleiad," Pleione one of the seven brighter stars,—the Daughter of Atlas, or the Seven Sisters, as they were called,—having wedded a mortal, hid her face in shame when she realized that her other sisters had married Gods. This story probably originated in an actual varia-

tion in light, for the spectrum of Pleione, the weaker of the seven brighter stars, resembles that of novæ after they have waned in brightness. A passing reference was made to the ancient Egyptians' study of the stars and of the Pleiades in particular, some of their pyramids having openings specially placed for the observation of this constellation.

In literature the Pleiades are frequently mentioned, for example, in Job occurs the passage, "the sweet influences of the Pleiades" which harks back to the springtimes about 2200 B.C. when the Pleiades were in the line of intersection of the planes of the earth's equator and the earth's orbit.

The fact that festivals were held and disaster associated with the time of midnight culmination of the Pleiades by such scattered tribes as ancient Egyptians, Persians, Druids, Japanese, Mexicans and South and North Americans, probably indicates that some great calamity such as a dulge did occur at this time in the dim past, and the constellation was held responsible.

Lastly, the revelations of modern astronomy with regard to the constellations were mentioned. Over 4000 stars are now known to be within the limits of the group. Almost all the stars investigated are found to have the same motion in space, and further, they have for the most part similar spectra, so it is inferred that they belong to the same cluster. The average distance of the stars is about 250 light-years. A photograph showing the nebulous formations in the group was thrown on the screen along with others depicting various mythical conceptions of the Pleiades.

At the close of the lecture, a vote of thanks to Mr. Harper was proposed by Dr. A. McGill and heartily endorsed.

R. E. DeL.

At Hamilton

November 8, 1912.— The first meeting of the Session of 1912 was held this evening.

Dr. Marsh was to have lectured on "Astronomical Terms," but owing to the critical illness of his father was unable to be present.

Mr. H. B. Collier, of Toronto, formerly of the Peterborough Centre, gave a very interesting address on "Meteorites." The lantern slides were very good, showing most of the notable meteorites now in the different museums and weighing from a few pounds up to 36½ tons.

The various compositions of Siderites, Siderolites and Aerolites were described, also the peculiar markings disclosed by polishing and etching.

The lecture was very much enjoyed by all, several being led to ask questions which the lecturer answered.

November 22.—Dr. C. A. Chant, of Toronto, was listened to with much interest and profit by a large audience on the subject, "Dark Stars; the Astronomy of the Invisible."

The tremendous expenditure of energy by the sun was described; this stated in figures is too great to be realised, the following from Young's book on "The Sun," originally given by Sir John Herschel, being more easily grasped.

A column of ice 2½ miles square reaching from the earth to the sun would be melted in one second if all the energy radiated by the sun were concentrated upon it, and in 7 seconds would be converted into steam.

This cannot last forever; we should, therefore, expect the sun to get cooler and darker, till at last it ceased altogether to give out light and heat.

Confirmations of this theory were to be found in the heavens and that from several sources.

1st. A sun rising to a high temperature and then cooling would show various colors in the course of its evolution from blue to white to yellow to red. We find examples of all such in the heavens.

2nd. The spectroscope supplements the telescope showing variations in spectra, changing from helium and hydrogen lines to those indicating metal vapors, to carbon and titanium absorption spectra.

3rd. The irregularities observed in the proper motion of

certain stars led to the opinion that they had attendant companions. This was verified by the telescope discovering them in some cases; but in others they could not be seen and the theory was that these companions were in some cases dark bodies. This was practically proven by the observing of such variables as Algol.

At the close of the meeting many questions were asked. Several remaining after the close to ask for further information.

T. H. W.

At Peterborough

November 5th, 1912.—The meeting of the Society, held in the Collegiate Institute, was well attended, and proved a most enjoyable session. The feature of the evening was an address by Rev. Dr. Marsh, who gave some very interesting information in regard to the dedication of the new Observatory at Allegheny, Pa. The Observatory was presented to the trustees of the University of Pittsburg, by Dr. John Alfred Brashear and accepted on behalf of the trustees by Dr. Samuel Black McCormick. A paper on "The Responsibility of the Observatory Staff" was given by Professor Frank Schlesinger, the Director. An able address was given by Professor Edward C. Pickering, Director of Harvard College Observatory, who was honored by being given the degree of Doctor of Letters.

Rev. Dr. Marsh showed slides of the three-domed Observatory. One of these domes, sixty feet in diameter, was occupied by the 26-inch telescope, presented by the Thaw family. The second dome covered the telescope in memory of the late Professor Keeler, virtually the founder of the present Observatory. The third dome is not yet occupied.

Rev. Dr. Marsh also gave a resume of the fourteenth meeting of the Astronomical and Astrophysical Society, of which Professor Pickering is President and Miss Annie J. Cannon, of Harvard College Observatory, Secretary.

November 26.— At the regular meeting of the Society held in the Collegiate Institute this evening, Mr. H. O. Fiske, President, was in the chair.

After Mr. Hal. Crane had given an interesting account of his observations with the Stratton telescope, Mr. J. R. Collins, of Toronto, addressed the Society on the subject of "The Motion and Distance of the Stars." Modern methods of determining these were presented in a highly interesting manner.

D. B. M.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

October

Temperature.— The mean temperature was below the average over British Columbia, Alberta, a large portion of Saskatchewan and in Western Manitoba; elsewhere in the Dominion it was above the average. Positive departures of 3 to 4 degrees occurred in the Ottawa and St. Lawrence Valleys while the chief negative departures, amounting to about 3·5 degrees, were recorded in northwestern Saskatchewan and on Vancouver Island.

Precipitation.— The precipitation was above the average in Eastern Ontario, over the whole of Quebec, the larger portion of New Brunswick and in Southern British Columbia; elsewhere it was below the average.

In Eastern Quebec and in New Brunswick the rainfall was heavy, varying from four to seven inches; whereas in the Western Provinces it was quite light, only a few localities reporting a total fall for the month of much over half an inch. Light snowfalls or flurries occurred in some places.

November

Temperature.—The mean temperature was above the average over the greater part of the Dominion, Northern British Columbia and Northern New Brunswick alone showing subnor-

mal values. In the Western Provinces, the excess above average ranged between 5° and 10° ; in Ontario between 1° and 3° ; and in Quebec and Nova Scotia between 1° and 2°.

Precipitation.— Precipitation was decidedly deficient in the Western Provinces and in New Ontario and in excess of the average over a portion of Ontario lying between Lake Huron and the Ottawa Valley and also throughout the Province of Quebec, elsewhere departures from average were not pronounced. Snow occurred in all the provinces.

Temperatures for October and November, 1912

Station	October		November	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	58	10	36	-18
British Columbia				
Atlin	52	22	38	-10
Agassiz	64	33	55	31
Barkerville	56	12	44	8
Kamloops	70	24	54	20
New Westminster	63	32	54	29
Prince Rupert	58	28	52	26
Vancouver	58	34	52	32
Victoria	64	34	55	33
Western Provinces				
Battleford	74	22	46	16
Broadview				
Calgary	70	14	58	12
Carman				
Edmonton	74	16	54	10
Medicine Hat	74	22	60	8
Minnedosa	76	16	52	4
Moose Jaw	85	18	63	5
Oakbank	73	19	47	15
Portage la Prairie	77	20	53	9
Prince Albert	70	20	44	8
Qu'Appelle	74	20	60	6
Regina	80	16	55	5
Swift Current	76	20	60	14
Winnipeg	74	20	49	14
Ontario				
Agincourt	74	28	59	17
Aurora	73	25	57	12
Bancroft	75	21	57	- 2
Barrie			57	14
Beatrice	75	22	58	4
Birnam	75	30	61	18
Bloomfield	69	27	60	19
Brantford	77	27	62	18
Bruce Mines	79	24	53	8
Chatham	81	30	67	19
Clinton	75	29	59	22
Cottam	80	28	65	11
Gravenhurst	76	21	58	6
Guelph				
Haliburton	77	19	59	2
Hamilton				
Huntsville	76	22		
Kenora	65	25	45	15
Kinmount	75	20		
Kingston	69	25	58	21
Lakefield	73	29	60	17
London	78	27	62	18
Lucknow	75	25	58	14
Madoc	76	22	61	10
Midland	80	40	60	30
North Gower				
Otonabee				
Ottawa	74	28	59	6
Owen Sound				
Paris	76	30	60	21
Parry Sound	72	26	63	12
Peterboro'	77	24	58	9
Port Arthur	74	21	48	3
Port Burwell	69	28	58	16
Port Dover	71	29	64	17
Port Stanley	69	28	56	18
Ronville			59	12
Sarnia				
Southampton	75	32	60	22
Stonecliffe	78	22	50	8
Stony Creek	77	33	62	22
Stratford				
Toronto	74	30	59	23
Uxbridge	72	26	56	9
Wallaceburg	71	27	56	22
Welland	71	30	60	19
White River	74	18	48	12
Quebec				
Brome	72	23	59	7
Father Point	68	28	56	12
Montreal	71	30	59	16
Quebec	70	28	48	9
Sherbrooke	74	24	61	13
Maritime Provinces				
Charlottetown	70	32	60	18
Chatham	78	26	58	14
Dalhousie	75	21		
Fredericton	78	25	64	12
Halifax	76	28	64	18
Moncton	75	24	67	15
St. John	68	32	58	20
St. Stephen	79	24	67	15
Sussex	74	25	64	13
Sydney	73	29	64	24
Yarmouth	66	31	62	26

MAGNETIC OBSERVATIONS

During the months of October and November the magnetic forces, as shown by the photographic curves, continued very quiet, October 1, 4, 8, 9, 11 to 17, 20 and 28 and November 1, 2, 9 to 11, 14 to 17, 22, 23 and 26 were days of slight disturbance, the most active one being on the 14th of October when the range in Declination was 38·6 minutes and in Horizontal Force ·00103 of a dyne.

In the following table an abstract of the results of magnetic observations at Agincourt for October and November is presented.

Declination

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes--Mean Daily	
							From hourly readings	From Means of Extremes
1912	° ′	° ′		° ′		° ′	′	′
Oct.	6 13·7	6 24·3	14	5 45·7	14	0 38·6	7·7	11·7
Nov.	6 14·2	6 35·5	14	5 58·3	14	0 37·2	5·7	10·9

Bifilar—C.G.S. Units

Oct.	0·16162	0·16193	11	0·16090	14	0·00103	0·00029	0·00038
Nov.	0·16163	0·16189	9	0·16085	14	0·00104	0·00018	0·00035

Inclination

Month	Mean Dover No. 2-20	Mean Earth Inductor
	° ′	° ′
October	74 40·3	74 40·3
November	74 40·4	74 40·5

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1912	P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1188	Oct. 12	15 32·8	V$_2$ 15 38·3	16 1·5	17 21·0	0·8	1 38·2	L.Ws. lasted a long
			L 15 53·7	16 5·9		0·9		time.
1189	" 17	10 45·9	11 1·3	11 4·0	11 51·0?	0·3	1 5·1	
				11 5·6				
1190	" 18	12 14·2	L 12 27·3	12 32·6	13 57·3	2·3	1 43·1	P.Ts. lasted a long
		V$_2$ 12 22·0	L 12 31·2	12 34·4		2·9		time.
1191	" 20	10 43·8?		10 47·0	11 2·3	0·2	0 18·5	
		10 44·8						
1192	" 26	10 6·1			10 38·6	0·05	0 32·5	
1193	" 31	18 20·7?	V$_2$ 18 33·4	18 40·8	20 18·7	0·3	1 58·0	
		18 23·5	L 18 40·4	18 45·4		0·3		
1194	Nov. 7	7 49·0	7 59·2	8 1·0	10 23·7?	5·4	3 01·5	Alaska.
		V$_2$ 7 55·9	8 00·1		10 50·5			
1195	" 7	16 57·3		17 3·0	17 37·4	0·9	0 40·1	Two strong shocks
		V$_2$ 16 59·8						separated by an in-
1196	" 7	17 42·2	17 47·5	17 48·4	18 51·2	1·5	1 9·0	terval of an hour
		V$_2$ 17 44·8						reported from Ni-
1197	" 17	1 35·0			2 4·2	0·2	0 29·2	caragua.
1198	" 17	11 51·0		11 52·0	12 10·8	0·3	0 19·8	
1199	" 19	14 1·0	14 11·1	14 15·1	15 34·5	1·7	1 33·5	Eq. reported from
		V$_2$ 14 5·9	14 12·9					Mexico City at 7.15
1200	" 19	15 59·7			16 2·0	0·05	0 2·3	N. to S. movements.
1201	" 22	1 12·8			1 21·0	0·2	0 18·2	Walls cracked.
								Eq. reported from Vancouver Isl'd just before 5 p.m. Dura- tion 6s N to S. move't.

Period 17·7 seconds. 1 mm. = 0″·41.

VICTORIA, B. C.

E. B. REED, SUPERINTENDENT.

No.	Date 1912	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1196	Oct. 12	15 30·7 V 15 34·4	15 42·6	15 47·3	17 9·0	0·8	1 38·3	
	" 17	Apparently an eq. dis. 10.33 masked by air currents.			10 11.05			
1197	" 18	12 4·5 V 12 7·7	12 10.9	12 15·7 12 28·7	13 57·2	1·1 1·3	1 52·7	An active disturbance
1198	" 20	10 34·9			10 57·3	0·05	0 22·4	
1199	" 26	9 50·3? 9 53·8 ?			10 21·5	0·05	0 31·2	Beginning doubtful.
1200	" 31	17 47·3			17 51·4	0·1	0 04·1	
1201	" 31	17 55·3 V 18 6·6	18 11·0 18 27·1	18 40·0	19 11·0	0·3	1 15·7	May be a continuation of last disturb.
1202	Nov. 2	14 4·5			14 37·9	0·2	0 33·4	Pronounced thick'ng.
1203	" 7	No P.Ts. V 7 44·8	7 48·8	7 49·3	10 18·5	5·3	2 33·7	Alaska.
1204	" 7	17 14·1 V 17 15·4	17 20·2	17 23·2	17 53·4	1·0	0 39·3	Eq., reported from (Nicaragua, San Juan (Two strong shocks (separated by an interval of an hour.
1205	" 7	17 53·4 17 56·2	V 17 59·6 L 18 7·7	18 8·5	18 54·0	1·4	1 00·6	
1206	" 13	1 25·0			1 35·1	0·05	1 10·1	
1207	" 17	12 3·4 V 12 10·3		12 11·1	12 19·1	0·2	0 15·7	No definite max.
1208	" 19	14 1·7 V 14 3.0	14 13·6	14 14·5	15 23·2	9·2	1 21·5	Eq. reported from (Mexico City at 7.15 (N and S movements.
1209	" 19	15 51·0				0·05		
1210	" 22	0 57·1	0 57·8	0 57·9	1 6.0	8·9	0·7	Abrupt dis. eq. in Vancouver Island just before 5 p.m.

Period 18 seconds. 1 mm. = 0″·54

J. V.

ASTRONOMICAL NOTES

Is the Earth Shrinking?—Mr. F. J. M. Stratton, in replying to a letter from Mr. Birrell, discusses briefly the secular cooling of the earth's crust. He sums up with the statement that, on the whole, students of cosmogony (as opposed to geology) are in agreement in accepting the hypothesis of secular cooling. The one notable exception is Professor F. R. Moulton, in whose Planetesimal Hypothesis secular cooling and initial high velocity of rotation for the earth have no place.—*Journal British Astronomical Association*, No. 2.

The Distribution of Galactic Objects.—E. Hertzsprung. The Milky Way or Galaxy can be regarded as a distribution forming a belt in the sky, and its general position may be defined by a great circle or equator marking out the centre of the band, and this great circle will have two poles, the north and south galactic poles. In the same manner the poles of any other group or distribution of objects can be determined roughly. Dr. Hertzsprung has considered seven different groups of objects: (1) Helium stars, 1,402 in number; (2) Occulting Variables; (3) *c* and *ac* stars; (4) Stars of Type V.; (5) Gaseous nebulæ (omitting those in the Magellanic clouds); (6) Stars of Type IV.; (7) Variables of the δ Cephei type.

He finds that all these seven systems have their poles near the galactic pole; the pole of the group of helium stars is seven degrees from the galactic pole, and the poles of the other six systems are all within six degrees of the galactic pole.—*Journal B. A. A.*, No. 1.

THE ORIGIN OF THE HIMALAYA MOUNTAINS.—In *Professional Paper*, No. 12, Survey of India, Col. S. G. Burrard, Surveyor-General of India, gives the details of some gravity work of the Survey and the conclusions he derives therefrom, a popular account of which he gave in a lecture reprinted in this Magazine for May and June last. It may be remembered that several years ago Col. Burrard showed that there appears to be a subterranean mass of great density lying across India in mean latitude 23° North. He now shows that the observations indicate the existence of a line of low density between this subterranean mass and the Himalayas, and suggests that there was, or is, one long crack in the earth's sub-crust extending from Sumatra round the Arrakan coast across Northern India, through the Persian Gulf to the Mediterranean, traces of which are seen in the parallel shores of the Gulf of Oman and of the Persian Gulf. The crack has been filled with alluvial deposit across Northern India and in other places, but the Himalayas remain as the result the rift in the earth, a great mass of matter having been pushed northward. It has been supposed by others that the Himalayan range was formed by the southward advance of the northern part of the Asiatic continent on to the Indo-African tableland.—*Observatory*, No. 454.

THE SOUTHERN MILKY WAY.—In the *Annals* of Harvard College Observatory, Vol. 72, No. 3, Professor Solon I. Bailey gives an account of a series of long exposure photographs of the southern Milky Way, illustrated by nine plates which together cover the southern 180° of the Galaxy. The instrument employed was a Cooke lens, about one and a half inches in diameter, mounted equatorially and driven by electric impulses furnished every second. The focal length was about thirteen inches and the field covered upon an 8 × 10 plate was about 30° by 40°, or one-fortieth of the whole sky. The definition is good over the greater part of each plate, the images being seriously distorted only by the effect of differential refraction over so large a field during a long exposure. The durations of the exposures range

from $10^h\ 43^m$ to $21^h\ 0^m$, each requiring from two to five nights. A great wealth of detail in the structure of the Milky Way is shown upon these plates. The background over much of the area is apparently nebulous, overlaid or broken up by a great variety of dark holes and lanes.

All the photographs were taken at Hanover, Cape Colony, by Mr. L. G. Shaltz and Professor Bailey. Hanover is situated on the vast plateau of South Africa, in the Great Karroo, at an elevation of 4,500 feet.— *Popular Astronomy*, No. 8.

Rotation of the Earth.—Two incidents connected with the rotation of the earth may be set down here. In his lecture on "Radiation" at Cambridge, Sir Joseph Larmor remarked that light-pressure was undoubtedly stopping the rotation of the earth; but only very slowly — calculation gave the effect as only about 1/1000th of that from the Tides. The other is the proof of the rotation by means of Atwood's machine, submitted by Father Hagen to the Mathematical Congress at Cambridge. The principle is the same as the proof suggested by Newton in 1679 — a body falling freely will fall to the east of the point indicated by a plumb-line. But in this form of the experiment the accidental error is large — so large that falls often occur to the west, though the average easterly deviation emerges from a number of falls. In Father Hagen's experiments the falls were consistently to the east throughout, with even a small fall such as can be exhibited in a lecture-room.— *Observatory*, No. 453.

The Systematic Motions of Sun-Spots.— Acting on a suggestion conveyed to him by the statement that "the rotation periods given by different spots in the same zone of latitude differ more widely than do the mean rotation periods for different zones of latitude," given in Mr. and Mrs. Maunder's paper on "The Solar Rotation Period," Professor Hirayama has analysed the motions of spots given in the Greenwich, Carrington's, and Sporer's publications and finds that apparantly there are two drifts of sun-spots exhibiting distinctive systematic motions. The angular velocity of drift i. is represented by

$\xi = 14{\cdot}37° - 2{\cdot}97° \sin^2\lambda$ (where λ = the heliographic latitude), and of drift ii. by $\xi = 14{\cdot}69° - 2{\cdot}65° \sin^2\lambda$; the former agrees fairly well with the mean values found by other investigators, while the latter exceeds it, showing a mean rate about 0·35° greater than that indicated by drift i. For the lower latitudes, the rotation period proper to drift ii. agrees fairly well with that found spectroscopically by Messrs. Storey and Wilson, and Professor Hirayama suggests that possibly certain groups of spots, by a proper motion of their own, come to the same level as the chromospheric layer investigated spectroscopically, and attain its angular velocity. He also suggests that this idea of two drifts may explain the distribution of sun-spots with different rotation periods in any particular zone of latitude. The data considered by him show that there are about twice as many sun-spots collected in drift i. as in drift ii.—*Nature*, No. 2241.

An Instance of Scientific Accuracy.— If Pittsburgh does not know what a distinguished scientist it has in its Observatory it should have heard Dr. Edward Pickering tell his audience of the work and wonderful achievements of its Director, Frank Schlesinger. He has become a great expert and authority on stellar parallaxes and spectroscopic binaries and his work is quoted all over the world. He has attained astonishing accuracy in determining the distances of stars by photographic processes. The measuring of the parallax of the nearest stars or angle subtended by the diameter of the earth's orbit at the distance of the stars, is the same as measuring the height of a man at a distance of two hundred miles; yet Professor Schlesinger has determined this to within one inch. The North Pole wanders around within a circle or fence only seventy feet in diameter, and the position of the pole has been determined within two or three feet. These are instances of the marvellous accuracy attained by modern instruments and methods in measuring astronomical distances, and some of the best work in this line is now being done right here in smoky Pittsburgh. And it might be said that it has been discovered that the smoke of this city in some ways adds to the efficiency of the telescope by cut-

ting off the disturbance of the sun's heat. In a conversation with Dr. Pickering we asked him if the 30-inch telescope in the Allegheny Observatory is one of the greatest telescopes in the world. "It will be," he answered, "with Professor Schlesinger behind it."— *Popular Astronomy*, No. 8.

A Comet that Discovered a Man. — Director Schlesinger in giving an account of the work that is being done at the Allegheny Observatory said that astronomers do not aim at making startling discoveries, but rather at carrying on the daily routine of observation and working at old problems. There might well be written over the door of an observatory, he said, the legend; "Abandon hope of making discoveries, all ye who enter here." He illustrated the point by saying that sometimes a discovery made the man rather than the man made the discovery, and told of the case of an obscure astronomer down in Nashville who discovered a comet. This drew attention to the astronomer, who was then called to the Lick Observatory, where he made no more discoveries, but is doing patient, faithful and fruitful routine work. "So in this case," said Mr. Schlesinger, "the comet may be said to have discovered the man, rather than the man the comet." It is often so in life. It is not the men who are seeking to do sensational things and attract attention to themselves who are doing the most useful work, but they who patiently pursue the path of daily duty and let come what will. They may not discover a comet but some comet may discover them, or at least their service will not be forgotten and their true reward is sure.

The reference is doubtless to Professor E. E. Barnard, who, however, made his greatest discovery, that of the fifth satellite of Jupiter, while at the Lick Observatory. He is now an astronomer at the Yerkes Observatory and doing most valuable work with the 40-inch telescope, as well as with the Bruce telescope. —*Popular Astronomy*, No. 8.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to secure Answers to Queries.

Queries

1. A number of observations show different velocities according as the H and K lines are used; if this means velocity of approach how can this occur?

2. How is the velocity of approach or recession as a whole disentangled from the orbital velocity of approach or recession?

3. Is the "second" spectrum that of the other component?

4. What are residuals?

5. Helium is a heavier gas than hydrogen, yet the hotter stars, or rather younger stars, are called helium stars. Does this gas make its presence evident before hydrogen does?—T. H. W.

Answers

1. The calcium lines H and K, whose wave-lengths are 3968 and 3933 tenth-meters, respectively, should, apart from accidental errors of measurement, give the same velocities. I know of no cases where they do not.

It is found, however, in some stars,—generally speaking, spectroscopic binaries,—that these calcium lines gives velocities different to, say, the hydrogen and helium lines. The number of such cases is too small yet to assign a general reason for such a characteristic behaviour. There may be a cause common to all, or each case may have its own particular explanation. Usually the velocities given by the calcium lines in such cases are approximately the same as that of the system as a whole: the inference might be made in such a case that the calcium layer surrounded the system and partook of its motion as a whole.

2. The measured velocities are always corrected for the earth's daily rotation and yearly revolution. When the period is obtained and all the observations are collected into one period we get the velocity curve from which all the elements can be obtained. If the curve should be a simple sine curve then the orbit is simply a circle and the velocity of the system would be the algebraic mean of the maximum velocities of approach and recession.

3. Yes.

4. If a person were measuring any quantity a number of times, each measure would differ from the others by amounts varying according to the precision of the work. The mean of the measurements would be considered as the best value obtainable, and the amount that each individual measurement differed from that mean would be considered its residual. In radial velocity work the residual is the amount that each observation differs from that value which it should have according to the elements accepted as final.

5. We can not say as yet that any class of stars, such as helium stars, are younger than any other type of stars. It is conventional to think of them as developing in the helium-hydrogen-solar order but it might just as well be in the reverse order.

Both hydrogen and helium lines occur at all stages in the so-called helium stars. When the helium lines reach their maximum intensity they are still considerably less intense than those of hydrogen. No helium lines occur in the hydrogen stars.

W. E. HARPER.

PECULIAR DEFLECTIONS OF THE PLUMB-LINE

That a near-by mountain deflects the plumb-line from the true vertical (*i. e.* the direction it would assume if the matter of the earth's crust were distributed uniformly over its surface) has long been known, and this effect has on several occasions been used to determine the mean density of the earth.

The first and the most familiar attempt to measure the

deflection for this purpose was made in 1774 by Maskelyne, the English Astronomer Royal, on Schiehallion a "hog-back" mountain about 3000 feet high running east and west in Perthshire, Scotland. The means for making the observations were furnished by King George III. Two stations were established in the same meridian, one on the north and the other on the south side of the mountain; and careful observations on stars near the zenith showed that the actual angle between the plumb-lines suspended at the two stations was about 53″, while independent measures of the distance of the two stations apart showed that if the mountain had been absent this angle would have been only 41″. There was a difference of about 12″. The density of the earth deduced was 4·7 times that of water.

In an address on "The Geology of India," printed in *The Observatory*, Col. S. G. Burrard, Superintendent of the Trigonometrical Survey of India, gives an interesting account of some of the peculiar results with the plumb-line obtained in India.

The great Tibetan table-land is about 1500 miles long, 300 miles wide and several miles high, and one would expect this great mass to give a decided deflection to the plumb-line. And so it does; but other results, not at all expected, have been observed.

At Darjeeling, up in the Himalayas, about 300 miles north of Calcutta, the deflection towards the mountains is 45″, and one would expect the deflection at Calcutta to be 25″. But at Silliguri, which is only 25 miles south of Darjeeling the deflection is only 16″ to the north, while at Jalpaiguri, 23 miles farther to the south, the deflection is 1″ in the opposite direction, that is away from the mountain!

At Calcutta the plumb-line also hangs slightly to the south. Such results have been observed in many other regions along the Himalayas. There is great attraction in the mountains, complete disappearance within a few miles of their foot, and then a reversal to the southerly direction. These results are corroborated by experiments with the pendulum.

Colonel Burrard endeavors to give an explanation of these

remarkable results. He believes the Indo-Gangetic plain to be a great crack in the earth's surface. The earth cracked along that line. On the south side of the crack the mountains of India have stood firm, unmoved, while the crack opened towards the north, forcing the earth's crust in that direction and crumpling it up to form the Himalayas. At present the crack is filled with light silt deposited by the rivers.

To account for the crack itself, Colonel Burrard suggests that in early ages, as the earth's rotation became slower, great strains were produced in the equatorial bulge, that the crust gave way and a crack developed, and a great mass was carried northward where it was straining to go. The crack may be slowly opening now; a number of earthquakes have occurred in that part of India during the last twenty years.

MORE INTERESTING PHOTOGRAPHS OF NEBULÆ

The nebulæ have an interest peculiarly their own. Their beautiful forms, their remarkable connection with the stars and the mysterious manner in which they pervade some parts of the heavens render the study of these strange objects very fascinating. Among the various forms the spiral is the most striking, and the profusion in which nebulæ of this type are found has led astronomers to devote much effort to portray them. The photographs obtained with the Crossley reflector of the Lick Observatory by Keeler and Perrine are well-known, and I have pleasure in calling attention to illustrations of three remarkable nebulæ which recently appeared in the *Publications* of the Astronomical Society of the Pacific, and which, by the courtesy of our brethren in the west, we are able to present here. (Plates XXXVI. and XXXVII.). Professor Heber D. Curtis, who is now in charge of the Crossley instrument, supplies the following account of them.

THREE INTERESTING SPIRAL NEBULÆ

A number of photographs have been made during the past year, with the Crossley reflector, of nebulæ hitherto unphotographed, and in the course of this work three nebulæ of rather unusual form have been discovered. Figure 1 shows

PLATE XXXVI.

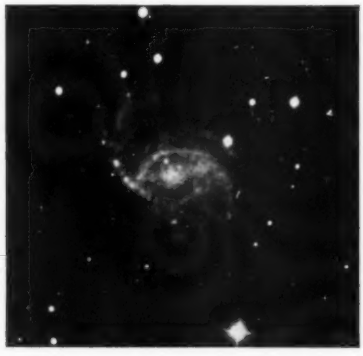


FIGURE 1.

THE SPIRAL NEBULA N. G. C. 5921.

Crossley Reflector. Exposure 3h.

FIGURE 2.

THE SPIRAL NEBULA N. G. C. 1300.

Drawn from a Crossley photograph.

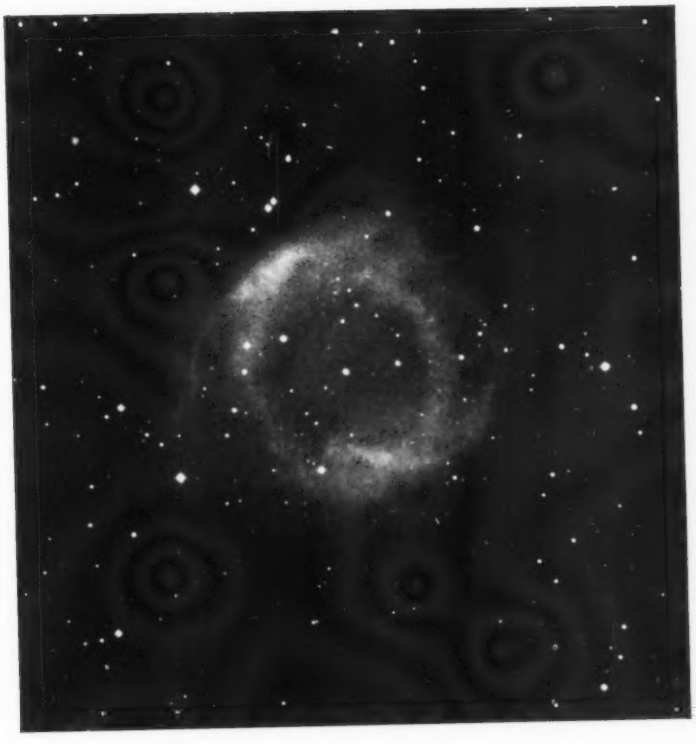


FIGURE 3.

THE HELICAL NEBULA IN AQUARIUS,

Crossley Reflector. Exposure 4h 10m.

the spiral nebula N. G. C. 5921 (α = 15h 17m·0; δ = + 5° 26′). It has a nebulous central star, and from this extends on each side a nearly straight line of matter from the ends of which spring two spiral branches; there are also a number of fainter spiral whorls. The central oval is about 1′·6 long. The photograph from which the cut was made was taken on June 10, 1912, with an exposure of three hours. It somewhat resembles N. G. C. 1300 (α = 3h 15m·2; δ = − 19° 49′), shown in Figure 2, which is a drawing made from a negative exposed two hours and ten minutes on September 16, 1912.

The nebula N. G. C. 7293 (α = 22h 24m·3; δ = − 21° 21′), shown in Figure 3, is a most interesting object, and, so far as I know, entirely unique among nebular forms. Discovered before 1824 by Harding, visual observations give absolutely no idea of its true form, and it is described in the N. G. C. of Dreyer as 2pF, vL, E or biN (Auw. 48)) It is 13′ in extreme diameter, making it the largest ring-formed object known, but from the original negative it is easily seen to be in reality about two turns of a helix. The negative from which the cut was made was exposed four hours and ten minutes on September 9, 1912. I would suggest that this interesting object be referred to as "The Helical Nebula in Aquarius."

A GREAT LOSS TO ASTRONOMY

In the death of Lewis Boss, which occurred on October 5, 1912, the world of astronomy suffered a great loss. Professor Boss was born at Providence, R. I., October 26, 1846. He was educated at Dartmouth College, where he received instruction in astronomy from the late Charles A. Young, graduating in 1870. After this he was associated with Professor C. L. Doolittle on the delimitation of the boundary between the United States and Canada from the Lake of the Woods westward, and in 1876 he was appointed director of the Dudley Observatory at Albany, N.Y., which position he held until his death. His work on the boundary led him to investigate in the most minute manner the positions of the stars, and in this branch of the so-called "old astronomy" he became the acknowledged leader.

From his observatory at Albany, of course, he could map only the northern stars, and when the Carnegie Institution of Washington organised a division of Meridian Astrometry he was put in charge of it and was able to extend his operations to the southern hemisphere. This work was entrusted to Professor

R. H. Tucker, of the Lick Observatory, who began his practical work in astronomy at the Dudley Observatory, and who was thoroughly familiar with the instrument Boss had used in his observations. Professor Tucker carried through the programme with his usual precision and with remarkable despatch.

The writer a few years ago had the pleasure of a brief visit to the Dudley Observatory. The director, in his knitted woollen observing cap, was busy with his great Meridian Circle, but readily spent some time in showing it to the visitor and in discussing the question of the locations of observatories. His chief contention was that an observatory should be put where it will be easily accessible, undoubtedly good advice, unless one has in view researches of a very special character, in which case it might be best to choose an isolated location.

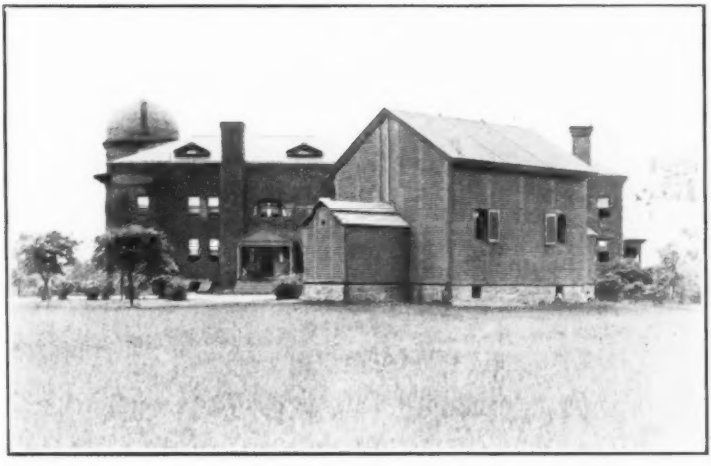
In the accompanying illustration is shown the rear of the Dudley Observatory. The present main building is a fine structure completed in 1893, and while it contains a 12-inch equatorial, this instrument had little attraction for Professor Boss. He preferred the more modest-appearing meridian circle, the house containing which is shown in the foreground of the photograph.

REPORT OF CHIEF ASTRONOMER, 1910, VOL. I.

It is interesting to see how the REPORTS OF THE CHIEF ASTRONOMER are growing in size, though certainly not deteriorating in quality. Volume I. for 1910 contains 470 pages, included in it being an account of the work done in :—"Seismology, Terrestrial Magnetism and Gravity," by Otto Klotz ; "Astrophysics," by J. S. Plaskett ; "Meridian Work and Time Service," by R. M. Stewart ; "Latitude and Longitude Work," by J. Macara ; "Precise Levelling," by F. B. Reid.

"Geology of the North American Cordillera at the Forty-Ninth Parallel," by R. A. Daly, will appear in volumes II. and III.

In this JOURNAL some of the results given have already been published, but the REPORT contains all the details of the



DUDLEY OBSERVATORY, ALBANY, N.Y.

Rear view, showing Meridian Circle House containing Professor Boss' famous Instrument

many investigations carried on under the Chief Astronomer, who is to be congratulated on the great amount of this high-class scientific work.

ASTRONOMICAL SOCIETY OF WALES

The *Journal* of the Astronomical Society of Wales for 1911 has recently been received by the Editor. It is a carefully prepared and well illustrated booklet, containing interesting papers on "Some Recent Advances in Astronomy," by Professor J. G. Smith, M.A.; "Biology in Relation to the Universe," by T. H. Burlend, M.A., B.Sc.; "The Nebular Hypothesis," by D. G. Taylor, M.A.; "The Researches of Professor Lowell," by P. Seward; and "On Finding a Curve very nearly representing the Path of a Disturbed Comet," by H. S. Williams, M.A., F.R.A.S.

The Society's headquarters are at Cardiff, and the *Journal* contains a portrait of the Lord Mayor and of several of the public buildings of the city.

We wish our sister society continued success.

WHERE IS THE "BIG DIPPER" IN THE AUTUMN

I thought everyone could identify the "Big Dipper," and that in early evening in the autumn it was to be found below the pole and right-side-up. I was, therefore, somewhat surprised to read in the *Christian Guardian* (Toronto) for December 4, 1912, in an article entitled "Some Winter Stars," supplied by a contributor who writes gracefully on literary subjects, the following:—

> About eight o'clock on the 1st of November one sees the Dipper above the Pole Star upside down. As it moves on in its tireless journey round the pole, in a few hours one sees it to the left of the Pole Star, with its handle standing almost straight up above the basin. A few hours more and one sees it beneath the Pole Star, standing properly, as a dipper should, and in no danger of spilling its contents. A few hours more brings it round to the right of the Pole Star, standing on the end of its handle, basin up in the air, as it were; but in all these positions

"The Pointers," ever true, still point to the lode-star, or the Pole Star, the mouth of the dipper always facing the pole. In the early evening in December look for the Dipper to the left of the Pole Star; in January look below the Pole Star, and in February look to the right of the Pole Star.

Farther on in the article occurs the following :—

Two of our most magnificent stars, Capella and Arcturus, are situated one on each side of the Big Dipper. Draw an imaginary line through the two stars that form the top of the Dipper, and prolong this line on the side farthest from the handle until you reach a very bright star giving out a white light with a slight tinge of yellow. There is no possibility of mistaking it, as there is no other star near it bright enough to be confused with it. Some of the best authorities class Capella as the brightest star in the northern hemisphere of the skies. It is above the horizon twenty hours out of every twenty-four, setting for four hours only, so that it can be seen at some time of night every month in the year when the sky is clear. In late November and early December, Capella may be seen shining directly overhead early in the evening.

It may be remarked that in the latitude of Toronto Capella is above the horizon $22^h\ 41^m$, while for any place more than thirty miles north of Toronto, that is, in much of Ontario, in the Western Provinces and in most parts of the Northern States it never sets. Further, on December 1 it does not come overhead (*i. e.* reach the meridian) until 1 a.m.

The attention given to elementary astronomy by our daily and weekly papers is encouraging, but one would wish that the information given were always entirely trustworthy.

BELATED COMET HUNTERS

The first comet to be sighted in 1912 was discovered on September 8 by Gale at Sydney, Australia. Mr. R. M. Motherwell, who has the chief custody of the comets at the Ottawa Observatory, was in the writer's office on September 12, and the comment was made that not a comet had then been reported in 1912. Next day the Harvard *Bulletin*, No. 494, arrived, announcing the discovery. Continued cloudiness prevented effective observation of the comet in Toronto.

The writer has examined the lists of discovered comets and

finds that not since 1841 has the first comet been discovered so late in the year. In 1841 not a comet was observed. There are now three comets to the credit of 1912. In 1905 there were three, in 1901 two and in 1900 three, though the average is about five per year.

Comet 1912*b* was discovered by Schaumasse at Nice on October 18, and it was soon shown to be indentical with Tuttle's comet, discovered at the Harvard College Observatory on January 4, 1858, which again was shown to be the same as Méchain's Comet of 1790.

Comet 1912*c* was discovered on November 2, by Borrelly, at Marseilles.

HOW COULD IT BE DONE?

Great regret was felt when the "Royal George" ran on the rocks below Quebec early in November, and apparently no effort was omitted to save the ship, happily with success. One means taken is described in "Canada's National Newspaper" in an interview with Mr. D. B. Hanna, Third Vice President of the Canadian Northern Railway, who is quoted as saying:—"The pumps are now working in the holds and it will be necessary for us to get enough of them working so that if the vessel is taken off the rocks we will be able to pump out two gallons to every one that runs in."

C. A. C.

INDEX TO VOLUME VI.

A

Anderson, G. R., The Scientific Application of Photography, 197.

Apex of the Sun's Way, John A. Paterson, 49.

Aspect of Mars in 1903, 74.

Astronomical and Astrophysical Society of America, Pittsburgh Meeting, *J. S. Plaskett*, 272.

Astronomical and Astrophysical Society of America, Washington Meeting, *C. A. Chant*, 24.

Astronomical Notes, 63, 139, 211, 258, 299, 366.

Astronomical Society of France, 65.

Astronomical Society of Wales, 377.

Astronomy as a Recreation, *Sir Joseph Pope*, 99.

Astronomy *vs.* Astrology, H. B. Collier, 131.

Astrophysics, *J. S. P.*, 290.

Astrophysics, An Excellent Primer of, 148.

B

Beatty, Samuel, Astronomical Weights and Measures, 200.

Belated Comet Hunters, 379.

Bigger, Charles A., The Geodetic Survey of Canada, 324.

Brashear, John A., The Making of Giant Telescopes and What They Will Do, 39.

C

Cannon, J. B., Orbit of ξ Persei from the H and K Lines, 188; The Orbit of γ Coronæ Borealis, 343.

Chant, C. A., Astronomical and Astrophysical Society of America, Washington Meeting, 24; Comets and Meteors—Strange Celestial Visitors, 88; Explanation of the Motion of the Planets, and of the Methods of Finding the Distances of the Fixed Stars, 123; In the Background of the Stars, 240; Notes and Queries, 68, 144, 216, 262, 304, 371.

Cluster Type, Variable Stars, 259.

Comets and Meteors—Strange Celestial Visitors, *C. A. Chant*, 88.

Comet that Discovered a Man, 370.

Constitution of the Ring Nebula in Lyra, 140.

Constitution of the Solar Corona, 140.

Contributions from Examinations, 147.

Convergent Stars, 215.

D

Dark Structures in the Milky Way, The, *T. E. Espin*, 225.

Death of an Early Member of the Society, 150.

Dedication of the New Allegheny Observatory, 264.

DeLury, A. T., Jules Henri Poincaré, 310; Theories of World Making, 1.

DeLury, R. E., The Solar Rotation, 198.

Discoverer of Nova Geminorum, 146.

Distance of the Stars, 260.

Distribution of Galactic Objects, 366.

Double Stars, 64.

Dutch Cheese, 149.

E

Earthquake Records at Toronto and at Victoria, B.C., *J. V.*, 56, 137, 207, 254, 296, 304.

Epicentres for 1911, Location of, *Otto Klotz*, 15.

Equipment of the Meteorological Observatory in 1853, 219.

Espin, T. E., The Dark Structures in the Milky Way, 225.

Explanation of the Motion of the Planets, and of the Methods of Finding the Distances of the Fixed Stars, *C. A. Chant*, 123.

F

Favorable Future Oppositions of Mars, 142.

Further Observations of θ Aquila, *W. E. Harper*, 265.

G

Geodetic Survey of Canada, The, *Charles A. Bigger*, 324.

German Compound Words, 259.
Great Loss to Astronomy, A, 375.
Great Telescope for the Allegheny Observatory, The, 213.

H

Harper, W. E., Further Observations of θ Aquila, 265; A Long-Period Spectroscopic Binary, 179.
Harvard College Observatory, 302.
Heavens through a Field Glass, The, T. H. Parker, 126.
How could it be done? 378.

I

In the Background of the Stars,, *C. A. Chant*, 240.
Instance of Scientific Accuracy, An, 369.
Intellectual Triumphs in Astronomy, 397.
Is the Earth Shrinking? 366.

J

Jenkins, G. Parry, The Orbs of Heaven, 202.

K

Klotz, Otto, Location of Epicentres for 1911, 15; Meteorological Phenomena, 42; The Moon, 124.

L

Latest Researches on the Planets, Especially Saturn, The, D. B. Marsh, 200.
Location of Epicentres for 1911, *Otto Klotz*, 15.
Long-Period Spectroscopic Binary, A, *W. E. Harper*, 179.
Lunar Exhibition at Barcelona, 263.

M

Magnetic Observations, at Agincourt, *R. F. S.*, 58, 138, 210, 253, 298, 363.
Magnetic Observations, at Ottawa, *Otto Klotz*, 53.
Mars: Is It Inhabited? T. C. Elliott, 132.
Meetings of Society:—At Toronto, 37, 120, 197, 246, 350; At Ottawa, 40, 124, 198, 353; At Hamilton, 47, 129, 200, 356; At Peterborough, 49, 131, 200, 246, 358; At Regina, 51, 247; At Guelph, 202.
Meteorology in Canada, *R. F. Stupart*, 75.
Meteorological Phenomena, *Otto Klotz*, 42.
Moon and the Weather, 262.
Moon's Diameter During Solar Eclipse, The, 258.
Moon's Orbit Around the Sun, The, *A. B. Turner*, 117.
Moon, The, Otto Klotz, 124.
More Interesting Photographs of Nebulæ, H. D. Curtis, 374.

N

New Astronomical Model, W. Park, 122.
New Comet, 261.
Note on Gelatine Used in Making of Light-Filters, 211.
Notes and Queries, 68, 144, 216, 262, 304, 371.
Notes from the Dominion Observatory, 53, 290.
Notes from the Meteorological Service, 56, 133, 203, 251, 293, 350.
Nova Geminorum, No. 2, 64.
Nova Geminorum, the Spectrum of, *J. S. Plaskett*, 27.

O

Observations of Jupiter's Galilean Satellites, 67.
Orbit of β Coronæ Borealis, The, *J. B. Cannon*, 343.
Orbit of ξ Persei from the H and K Lines, *J. B. Cannon*, 188.
Origin of the Himalaya Mountains, The, 367.

P

Peculiar Deflections of the Plumb-Line 372.
Pendulum, The, Wm. Trant, 248.
Photographing Halley's Comet with Home-Made Apparatus, *A. Young*,, 281.
Photographing Lightning, *A. Steadworthy*, 322.

Planet Jupiter, The, *Sir Joseph Pope*, 128.

Planet Mars, The, C. A. Chant, 49.

Planetary Atmosphere, G. H. Ling, 247.

Planetary Nebulæ, 299.

Plaskett, J. S., Astronomical and Astrophysical Society of America — Pittsburgh Meeting, 272; The Spectroscopic Binary θ^1 Tauri, 231; The Spectrum of Nova Geminorum, 27.

Pleasing Observation, A, 150.

Pope, Sir Joseph, Astronomy as a Recreation, 99; The Planet Jupiter, 128.

Popular Interest in Astronomy, 66.

Precise Levelling in Canada, *F. B. Reid*, 151.

Preliminary Tests of a Plane Grating Spectrograph for Stellar Work, *J. S. P.*, 290.

Preventing Dew-Deposit on Glass Surfaces, 63.

Q

Question of Keeping Time, The, 216.

R

Recent Investigations Concerning the Planets, Especially Saturn, Rev. Dr. Marsh, 48.

Reid, F. B., Precise Levelling in Canada, 151.

Removal of a Familiar Landmark, The 306.

Report of Chief Astronomer, 1910, Vol. I., 376.

Report of Weather in Canada, *S. F. S.*, 60, 133, 203, 251, 293, 360.

Reported Discovery of a New Comet, 143.

Resisting Medium in Space, 139.

Responsibilities of an Observatory Staff, *Frank Schlesinger*, 283.

Rotation of the Earth, 368.

Rotation Period of Uranus, 219.

S

Saturn's Rings, 63.

Scientific Work at Victoria, B.C., 150.

Solar Constant and Climatic Changes, The, 301.

Solar Eclipse of April 17, The, 212.

Southern Milky Way, The, 367.

Spectroscope Methods, 65.

Spectroscopic Binary θ^1 Tauri, The, *J. S. Plaskett*, 231.

Spectrum of Nova Geminorum, The, *J. S. Plaskett*, 27.

Spiral Nebulæ, 130.

Steadworthy, A., Photographing Lightning, 322.

Stellar Spectra, Brightness and Density, 302.

Stellar Universe, The, 300.

Strange Celestial Visitors — Comets and Meteors, *C. A. Chant*, 88.

Study of Solar Prominences, 299.

Stupart, R. F., Meteorology in Canada, 75.

Summer Constellations, J. R. Collins, 198.

Summer Philosophy, 221.

Suns and Systems of the Visible Universe, W. Balfour Musson, 47.

Systematic Motions of the Stars, 141.

Systematic Motions of Sun-Spots, 368.

T

Theories of Cosmogony, 71.

Theories of World-Making, *A. T. DeLury*, 1.

Time and Related Problems, L. B. Stewart, 40.

Time, Question of Keeping, 216.

Turner, A. B., The Moon's Orbit Around the Sun, 117.

V

Value of Scientific Research, 214.

W

Watch-Winding Problem, 305.

Where is the "Big Dipper" in the Autumn? 377.

Who is the Khan in the Moon? 264.

Y

Young, A., Photographing Halley's Comet with Home-Made Apparatus, 281.

Young, J., Earthquake Records at Toronto and at Victoria, B.C., 56, 137, 207, 254, 296, 364.